



***15TH TARGET FABRICATION
SPECIALISTS MEETING***

Technical Program and Book of Abstracts

June 1 – 5, 2003

Gleneden Beach, Oregon

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15th TARGET FABRICATION SPECIALISTS MEETING

June 1 through 5, 2003

Westin Salishan Lodge
Gleneden Beach, Oregon

PROGRAM

Sunday, June 1, 2003

REGISTRATION 6:30 – 8:30 PM Conference Registration and Reception

We will have refreshments and hors d'oeuvres

MONDAY, JUNE 2, 2003

7:30 – 8:00 AM

(Terrace Room)

Continental Breakfast

ORAL SESSION I

8:00-10:00 AM (Long House Ballroom)

Russell Wallace (Chair)

8:00 AM

Introduction and Welcome

Tom Bernat

8:10

M-1

The Research Program for the LMJ Cryogenic Target: Main Results and Prospects (Invited)

Ph. Baclet, F. Bachelet, S. Bednarczyk, R. Botrel, H. Bourcier, O. Breton, S. Charton, R. Collier, E. Fleury, C. Gauvin, O. Legaie, A. Longeau () D. Mary G. Moll, JP Perin (**) B. Reneaume, G. Talabart, M. Theobald, F. Viargues (**) CEA VALDUC-Laser Target Department (*) CEA Le Ripault-Organic Materials Department (**) CEA Grenoble - Very Low Temperature Department*

8:40

M-2

Project ORION; the next generation of high energy density physics research facilities in the UK to meet AWE needs

Tom Bett, (Atomic Weapons Establishment, United Kingdom)

9:00

M-3

Advances in Target Fabrication at Sandia National Laboratories

D.G. Schroen, C.O. Russell, J.E. Streit, D.L. Tanner, & S.C. Dropinski (Schafer Corporation & Sandia National Laboratories, New Mexico)

9:20

M-4

Recent Developments in Fabrication of Direct Drive Cylinder Targets for Hydrodynamics Experiments at the OMEGA Laser

A. Nobile, M.M. Balkey, J.J. Bartos, S.H. Batha, R.D. Day, J.E. Elliott, N.E. Elliott, V.M. Gomez, D.J. Hatch, N.E. Lanier, J.R. Fincke, R. Manzanares, T.H. Pierce, D.L. Sandoval, D.W. Schmidt, & W.P. Steckle (Los Alamos National Laboratory)

9:40

M-5

A Review of Development Activities for the AWE Experimental Laser Programme

Barrie Lewis (Atomic Weapons Establishment, United Kingdom)

10:00

Coffee Break

ORAL SESSION II

10:20 AM – 12:00 PM

Philippe Baclet (Chair)

10:20 AM

M-6

Fabrication of Fast Ignition Targets

D. Hill, A. Nikroo, J.L. Kaae, J.N. Smith, Jr., & D.A. Steinma (General Atomics)

10:40

M-7

The Use of Polyimide in the Fabrication of ICF Targets

Forbes Powell (Luxel Corporation)

11:00

M-8

Status of the Ice-Layering Development Effort at OMEGA

D.R. Harding, M.D. Wittman, L. Elasky, J. Sailor, & E. Alfonso (Laboratory for Laser Energetics)

11:20

M-9

Deuterium Solidification in Foam

R.Q. Gram, & D.R. Harding (Laboratory for Laser Energetics)

11:40

M-10

Modeling Temperature and Pressure Gradients During Cooling of Thin-Walled Cryogenic Targets

E.L. Alfonso, R.Q. Gram, & D.R. Harding (Laboratory for Laser Energetics)

12:00 PM

Lunch on own

1:30 – 5:00 PM Workshops and Small-Group Discussions

ORAL SESSION III

7:00 – 8:10 PM

Dave Harding (Chair)

- 7:00 PM M-11 Update on Ignition Target Designs for NIF
(Invited)
Steve Haan (Lawrence Livermore National Laboratory)
- 7:30 M-12 Recent Progress in 2-MM Diameter NIF Mandrel Production
Abbas Nikroo, Barry McQuillan, Masaru Takagi, & Robert Cook
(General Atomics & Lawrence Livermore National Laboratory)
- 7:50 M-13 Progress Toward Meeting NIF Specifications for Vapor Deposited Polyimide Ablator
Coatings
Stephan Letts, Mitchell Anthamatten, Steven Buckley, Evelyn Fearon, April
Nissen, & Robert Cook (Lawrence Livermore National Laboratory)

POSTERS

8:10 – 10:00 PM (Council House Room)

Dave Harding (Chair)

- M-P1 Target Insertion Cryostat Design Concepts for the NIF Cryogenic Target System
N.B. Alexander & R. Gallix (General Atomics)
- M-P2 MK-1 Closed Cycle Cryostat
R. Frazee, T. Bernat, V. Brugman, A. Debeling, B. Haid, & J. Stewart
(Schafer Corporation & Lawrence Livermore National Laboratory)
- M-P3 A Comparison of Liquid Helium-Based and Cryocooler-Based Target Cryostat Designs
B. Haid, T. Bernat, V. Brugman, A. Debeling, J. Stewart, & R. Frazee
(Lawrence Livermore National Laboratory & Schafer Corporation)
- M-P4 High Pressure Deuterium Fill System
J. Pipes, & J. Sater (Lawrence Livermore National Laboratory)
- M-P5 Mark-1 Liquid Helium Flow Cryostat
J. Stewart, T. Bernat, V. Brugman, A. Debeling, R. Frazee, L. Guillemet, B. Haid,
J. Perin, & F. Viargues (Schafer Corporation, Lawrence Livermore National
Laboratory, & CEA Service Des Basses Temperatures, France)
- M-P6 Effect of Low Mode Defects in PAMS Shells on Thick and Thin GDP Shells Made
Using the Depolymerizable Technique
A. Nikroo, J.B. Gibson, & E. Castillo (General Atomics)
- M-P7 Fabrication Techniques and Properties of Overcoated Resorcinol-Formaldehyde Foam
Shells
A. Nikroo, D.G. Czechowicz, A. Greenwood, R. Paguio, M. Takagi, & T. Woo
(General Atomics, Lawrence Livermore National Laboratory, & University of
California, San Diego)
- M-P8 A Spectroscopic Study of Curing of Vapor-Deposited Poly(amic Acid)

Mitchell Anthamatten, Katherine Day, Stephan A. Letts, Steven Buckley, Evelyn Fearon, April Nissen, & Robert C. Cook (Lawrence Livermore National Laboratory)

- M-P9 Development of PAMS for Laser Target Mandrels: Controlled Synthesis by Living Anionic Polymerization
A. Balland-Longeau, M. Calonne, J-M. Catala (CEA-Le Ripault, Departement Materiaux, & Institut Charles Sadron, France)
- M-P10 Oxygen Uptake by Plasma Polymer Materials
Steven Letts, Mitchell Anthamatten, Robert Cook, Abbas Nikroo, & Annette Greenwood (Lawrence Livermore National Laboratory & General Atomics)
- M-P11 Progress with AFM Spheremapping: Noise Reduction and Coverage Improvement
J.B. Gibson, R.B. Stephens, A. Nikroo, & J. Bousquet (General Atomics & San Diego State University)
- M-P12 Full-Wave and Ray Trace Calculations of Shadowgrams Compared with Measurements
J.D. Moody, & D. Bittner (Lawrence Livermore National Laboratory & Schafer Corporation)
- M-P13 Automated Batch Shell Characterization
H. Huang, R.B. Stephens, C. Lyon, & A. Nikroo (General Atomics)
- M-P14 Evolution of ICF Target Technology
W. J. Miller, & the GA/Schafer ICF Target Support Team
- M-P15 Recent Developments in Fabrication of Double Shell Targets for Experiments at the OMEGA Laser
A. Nobile, J.J. Bartos, R.D. Day, N.D. Delamater, J.E. Elliott, N.E. Elliott, V.M. Gomez, D.J. Hatch, G.A. Kyrala, R. Manzanares, T.H. Pierce, D.L. Sandoval, D.W. Schmidt, & W.P. Steckle (Los Alamos National Laboratory)
- M-P16 High Precision X-Radiography for Characterization of NIF Targets
R.B. Stephens, & G. Flint (General Atomics & Photera)
- M-P17 Cryogenic Pressure Loader Report: D₂ Target Filling and DT Leak Testing
Peter S. Ebey, James M. Dole, James K. Hoffer, Arthur Nobile, & John D. Sheliak (Los Alamos National Laboratory & General Atomics)
- M-P18 First Results on the Cryotarget Positioner Prototype for the Laser-Megajoule
D. Chatain, JP. Perin, V. Lamaison, P. Bonnay, D. Communal, G. Paquignon, D. Brisset, & B. Cathala (CEA, France)
- M-P19 Numeric Modeling of Optical Images of Spherical ICF Targets
Sergey M. Tolokonnikov & Andrey I. Nikitenko (Lebedev Physical Institute of the Russian Academy of Sciences, Russia)

TUESDAY, JUNE 3, 2003

7:30 – 8:00 AM		(Terrace Room)	Continental Breakfast
ORAL SESSION I		8:00 – 10:00 AM (Long House Ballroom)	Barrie Lewis (Chair)
8:00 AM		Announcements	
8:10	Tu-1	Progress in Direct-Drive Inertial Confinement Fusion Research at the Laboratory for Laser Energetics (Invited) <i>D.D. Meyerhofer (University of Rochester, Laboratory for Laser Energetics)</i>	
8:40	Tu-2	Overview of Foam Shell Fabrication for Use at LLE's OMEGA Facility <i>D.G. Czechowicz, A. Nikroo, R. Paguio, & M. Takagi (Lawrence Livermore National Laboratory & General Atomics)</i>	
9:00	Tu-3	Marangoni Instabilities in Microencapsulation <i>Pravin K. Subramanian, Abdelfattah Zebib, & Barry McQuillan (Rutgers - The State University & General Atomics)</i>	
9:20	Tu-4	Particulate Doping of TPX Foams <i>K. Youngblood, R. Chan, J. Dobbs, D.G. Schroen, & J.E. Streit (Schafer Corporation)</i>	
9:40	Tu-5	Characterization of Particulate Loaded Low Density Polymer Foams <i>Douglas Faith (Atomic Weapons Establishment, United Kingdom)</i>	
10:00		Coffee Break	
ORAL SESSION II		10:20 AM – 12:00 PM	Steve Letts (Chair)
10:20	Tu-6	Status of Polyimide Target Development Activities at LLE <i>A.K. Knight, F.-Y. Tsai, M.J. Bonino, & D.R. Harding (U of R, Laboratory for Laser Energetics)</i>	
10:40	Tu-7	Origin and Evolution of Structured Amorphous Films Prepared by Glow Discharge Polymerisation for ICF Experiments <i>M. Theobald, B. Dumay, C. Chicanne, J. Barnouin, O. Legaie, & P. Baclet (CEA, France)</i>	
11:00	Tu-8	Experiments Aimed at Understanding Solvent-Vapor Smoothing of Polymer Surfaces <i>Mitchell Anthamatten, Stephan A. Letts, Steve R. Buckley, April E. Nissen, Evelyn Fearon, & Robert C. Cook (Lawrence Livermore National Laboratory)</i>	
11:20	Tu-9	Aromatic Polyimides with High Performances and Deuteration <i>E. Anselmi, J. Raby, A. Balland-Longeau, P. Palmas, & D. Demattei (CEA – LeRipault, France)</i>	
11:40	Tu-10	Advanced Target Designs for the Direct-Drive Inertial Confinement Fusion <i>V.N. Goncharov, P.W. McKenty, D.D. Meyerhofer, S. Skupsky, T.J.B. Collins, P.B. Radha, & T.C. Sangster (U of R, Laser Laboratory for Energetics)</i>	

12:00 PM Lunch on own

1:30 – 5:00 PM Workshops and Small-Group Discussions

ORAL SESSION III

7:00 – 8:10 PM

Art Nobile (Chair)

- 7:00 PM Tu-11 The Path to Develop Laser Fusion Energy
(Invited)
John D. Sethian, & Stephen P. Obenschain (Naval Research Laboratory)
- 7:30 Tu-12 Production of Divinylbenzene Shells for the HAPL Program
J. Streit & D.G. Schroen (Schafer Corporation)
- 7:50 Tu-13 Fabrication of a Double Shell Target With a PVA Inner Layer
*D.A. Steinman, M.L. Hoppe, J.N. Smith, Jr., & R. Wallace
(Lawrence Livermore National Laboratory & General Atomics)*

POSTERS

8:10 – 10:00 PM (Council House Room)

Art Nobile (Chair)

- Tu-P1 Formation of a Thermostable Glassy Fuel Layer Using the Minor Dope Technique
*E.R. Koresheva, I.E. Osipov, O.V. Isheinov, T.P. Timasheva, A.A. Tonshin, &
L.S. Yaguzinskiy (Lebedev Physical Institute of RAS, Moscow, Russia & Institute
of Physics-Chemical Biology, Moscow State University, Russia)*
- Tu-P2 Parametric Study of Infrared Layering
*D. Bittner, J. Burmann, J. Moody, & W. Unites
(Schafer Corporation & Lawrence Livermore National Laboratory)*
- Tu-P3 Refractive Index Measurement of Solid Hydrogen
*Bernard J. Kozioziemski, & Daniel Stefanescu
(Lawrence Livermore National Laboratory)*
- Tu-P4 Accuracy Limits of Fuel Layer Characterization in an Indirect Drive Cryogenic
Hohlraum
J.D. Moody, B. Kozioziemski (Lawrence Livermore National Laboratory)
- Tu-P5 Design for Fiber Injection of IR into a Hohlraum
*R. Frazee, D. Bittner, J. Burmann, & B. Kozioziemski
(Schafer Corporation & Lawrence Livermore National Laboratory)*
- Tu-P6 IR Absorptive Properties of Plastic Materials Used in ICF Capsules
*Robert Cook, Mitchell Anthamatten, Steve Letts, Abbas Nikroo, & Don Czechowicz
(Lawrence Livermore National Laboratory & General Atomics)*
- Tu-P7 Mechanical and Permeation Properties of Thin GDP Shells Used as Cryogenic Direct
Drive Targets at OMEGA
*A. Nikroo, D.G. Czechowicz, K.C. Chen, M. Dicken, C. Morris, R. Andrews,
A. Greenwood, & E. Castillo
(General Atomics, University of California, San Diego & Cornell University,
New York)*
- Tu-P8 Plasma Diagnostic Study of the GDP Coating System Used for OMEGA Cryogenic
Target Fabrication

*A. Nikroo, P. Ross, D.G. Czechowicz, & M. Dicken
(General Atomics, Brigham Young University, Utah & University of California,
San Diego)*

Tu-P9 Details of the Coating Process and Materials Properties for Vapor Deposited Polyimide

*Stephan Letts, Mitchell Anthamatten, Steven Buckley, Evelyn Fearon, April Nissen,
& Robert Cook (Lawrence Livermore National Laboratory)*

Tu-P10 Implementation and Effects of Closed-Loop Controls on OPO IR Sources for Cryogenic Target Layering

*L.M. Elasky, D.J. Lonobile, W.A. Bittle, D.R. Harding, A.V. Okishev, & J.D. Zuegel
(U of R, Laboratory for Laser Energetics))*

Tu-P11 Fabrication of Laser Targets Requiring Novel Depositions

Rich Capps (Luxel Corporation)

Tu-P12 Fabrication of Foam and Film Targets for ICF

*J. Varadarajan, A. Velikovich, Y. Aglitsky, S. Carter, P. Collins, D. Mathews,
B.W. McQuillan, & T. Walsh
(Schafer Corporation, Naval Research Laboratories, & General Atomics)*

Tu-P13 Development and Fabrication of Targets for Materials Studies at the Los Alamos Trident Laser

*R.A. Perea, E.V. Armijo, R.D. Day, J.M. Edwards, F.P. Garcia, R. Manzanares,
A. Nobile, D. Paisley, R.J. Sebring, D.L. Sandoval, & R.C. Snow
(Los Alamos National Laboratory)*

Tu-P14 New ICF Target Development

*T. Walsh, D.G. Schroen, J. Varadarajan, & A. Nikroo
(Schafer Corporation & General Atomics)*

Tu-P15 Rapid Adaptability in Production Techniques for Complex Vulcan Experiment Targets

*M. Tolley, J.J. Spencer, M.J. Beardsley, P.E. Hatton, F. Jones, P.A. Norreys, & D.
Shepherd (CCLRC Rutherford Appleton Laboratory, UK)*

Tu-P16 Investigating Machining Variables on Various Substrates

*S. Carter, P. Collins, S. Faulk, D. Mathews, T. Walsh, & K. Youngblood
(Schafer Corporation)*

Tu-P17 Optimization of HIPE Foams

*W.P. Steckle, Jr., M.E. Smith, R.J. Sebring, & A. Nobile
(Los Alamos National Laboratory)*

Tu-P18 Fast Ignition Target Requirements

*R.B. Stephens, S.P. Hatchett, C. Stoeckl, K.A. Tanaka, & H. Shiraga
(General Atomics & Lawrence Livermore National Laboratory)*

WEDNESDAY, JUNE 4, 2003

7:30 – 8:00 AM

(Terrace Room)

Continental Breakfast

ORAL SESSION I

8:00 – 9:50 AM (Long House Ballroom)

Pete Gobby (Chair)

8:00 AM

Announcements

8:10

W-1

Shell-Target Formation and Installation to Produce Microspheres from Metastable Materials

N.G. Borisenko, N.A. Chirin, V.M. Dorogotvtsev, V.V. Gorlevsky, Yu.E. Markushkin, Yu.A. Merkul'ev, P.A. Storozhenko, & R.A. Svitsin (Lebedev Physical Institute, Bochvar Institute of Non-Organic Materials, GNIChTEOS, Russia)

8:30

W-2

An Overview of Beryllium Capsule Fabrication Activities at Los Alamos National Laboratory

Jason C. Cooley, D.J. Alexander, B.J. Cameron, L.B. Dauelsberg, R.D. Field, R.E. Hackenberg, J.M. Herrera, A. Nobile, P.A. Papin, G. Rivera, R.K. Schulze, & D.J. Thoma (Los Alamos National Laboratory)

8:50

W-3

Grain Refinement in Beryllium by Equal Channel Angular Extrusion

David J. Alexander, Michael E. Mauro, Jason C. Cooley, & Larry B. Dauelsberg (Los Alamos National Laboratory)

9:10

W-4

Microstructural Characterization of Be Capsule Bonds

R.E. Hackenberg, B.J. Cameron, J.C. Cooley, L.B. Dauelsberg, R.D. Field, A. Nobile, Jr., P.A. Papin, G. Rivera, R.K. Schulze, & D.J. Thoma (Los Alamos National Laboratory)

9:30

W-5

Sputter-Deposited Be for NIF Capsule Ablators

R. McEachern, C. Alford, J.P. Armstrong, & R. Gallix (Lawrence Livermore National Laboratory & General Atomics)

9:50

Coffee Break

ORAL SESSION II

10:10 AM – 12:10 PM

Rand McEachern (Chair)

10:10 AM

W-6

Computational Design of Infrared Enhanced Cryogenic Layering of ICF Capsules

R.A. London, D.N. Bittner, G.D. Kerbel, B.J. Kozioziemski, M.M. Marinak, & R.L. McEachern (Lawrence Livermore National Laboratory, & Schafer Corp.)

10:30

W-7

Infrared Formed And Controlled Fuel Layers Inside of Hohlräume

Bernard J. Kozioziemski, Richard A. London, Randall L. McEachern, & Donald N. Bittner (Lawrence Livermore National Laboratory & Schafer Corporation)

10:50

W-8

Calculating the Equilibrium Deuterium-Tritium Fuel Layer Thickness Distribution in a NIF Hohlraum Capsule

Jorge J. Sanchez, & Warren Giedt (Lawrence Livermore National Laboratory)

- 11:10 W-9 Effects of Cooling and Hydrogen-Ice Formation on the Out-of-Roundness of Cryogenic Fuel Capsules
*M.D. Wittman, L.M. Elasky, D.R. Harding, W. Seka, & A. Warrick
(U of R, Laboratory for Laser Energetics & Lawrence Livermore National Laboratory)*
- 11:30 W-10 Experimental Studies of Natural Convection Driven Asymmetries in Cryogenic Hydrogen Layers
*J.D. Moody, D. N. Bittner, W.H. Giedt, & J.J. Sanchez
(Lawrence Livermore National Laboratory & Schafer Corporation)*
- 11:50 W-11 Thermal and Hydrodynamic Study of Cryogenic Target for the LMJ
G. Moll, S. Charton, CEA/VALDUC, France
- 12:10 PM Lunch on own

ORAL SESSION III

1:30 – 2:50 PM

Don Bittner (Chair)

- 1:30 PM W-12 Indirect Drive LMJ Target Fabrication Specifications
S. Laffite, M. Bonnefille, F. Chaland, C. Cherfils, D. Galmiche, J. Giorla, P.A. Holstein, & Y. Saillard (CEA, France)
- 1:50 W-13 Inertial Fusion Cryogenic Activities at the CEA Low Temperatures Laboratory
J.P. Perin on behalf of SBT/Team
- 2:10 W-14 Conceptual Design of a Compact, Low Pressure Fill System for Cryogenic Targets
*Jorge J. Sanchez, T.P. Bernat, J. Burmann, W.H. Giedt, & J.D. Moody
(Lawrence Livermore National Laboratory)*
- 2:30 W-15 Experiments on Filling and Layering Capsules in Hohlräume
*J.D. Sater, B. Kozioziemski, J. Pipes, D. Bittner, J.D. Moody, & T. Bernat
(Lawrence Livermore National Laboratory & Schafer Corporation)*
- 2:50 Coffee Break

POSTERS

3:10 – 5:30 PM (Council House)

Don Bittner (Chair)

- W-P1 Development of Copper Doped GDP Coatings
*A. Nikroo, E. Castillo, A. Greenwood, & D. Hill
(General Atomics)*
- W-P2 Fabrication of Gas Filled Tungsten-Coated Glass Shells for HED Experiments
*A. Nikroo, W.A. Baugh, & D.A. Steinman
(General Atomics)*
- W-P3 Permeation Barrier Development for Multi-millimeter CH Capsules Used on the Z-machine
*D.A. Steinman, M.L. Hoppe, R. Andrews, A. Nikroo, & D.G. Schroen
(General Atomics & Schafer Corporation)*
- W-P4 Microstructures of Ultralow-Density TPX Foam Obtained by Altering the Coagulant Alcohol
Keiji Nagai, & Takayoshi Norimatsu (Institute of Laser Engineering (ILE), Japan)
- W-P5 Fabrication of Up to 4-MM Diameter Microencapsulated P_{MS} Mandrels for High Gain Target Designs

Masaru Takagi, Robert Cook, Barry McQuillan, Jane Gibson, & Sally Paguio

(Lawrence Livermore National Laboratory & General Atomics)

- W-P6 Beryllium Capsule Filling Equipment Design Studies
R. Gallix & N.B. Alexander (General Atomics)
- W-P7 Fabrication and Characterization of Targets for Shock Propagation and Radiation
Burnthrough Measurements on Beryllium-Copper Alloy
*A. Nobile, S.C. Dropinski, J.M. Edwards, R.W. Margevicius, R.E. Olson, G. Rivera,
& R.J. Sebrin (Los Alamos National Laboratory & Sandia National Laboratories)*
- W-P8 Design of Z-Pinch IFE Target Assembly
Chuck Gibson (Luxel Corporation)
- W-P9 Fabrication of Targets for Radiation Flow Experiments on the Sandia Z-Pinch Facility
*T.H. Pierce, J.J. Bartos, R.D. Day, J.E. Elliott, N.E. Elliott, V.M. Gomez, D.J.
Hatch, R. Manzanares, J.F. Poco, D.L. Sandoval, and D.W. Schmidt
(Los Alamos National Laboratory & Lawrence Livermore National Laboratory)*
- W-P10 Characterization of Fast Ignition Targets
*D. Hill, A. Nikroo, J.L. Kaae, J.N. Smith, Jr., & D.A. Steinman
(General Atomics)*
- W-P11 Surface Characteristics of Sputtered and E-Beamed Al Films on Extremely Smooth
Surfaces
E. Hsieh, T. Walsh, & B. Motta (Schafer Corporation)
- W-P12 Comparisons of the Hardnesses, Compositions, and Microstructures of Electroplated
and Rolled High-Purity Gold
J.L. Kaae, & D. Woodhouse (General Atomics)
- W-P13 The Oxidation Characteristics of Sputtered Mg Films
B. Motta & E. Hsieh (Schafer Corporation)
- W-P14 Polyimide Membranes for LIL Hohlraums
B. Reneaume, R. Caland, S. Meux, C. Gatteaut, E. Fleury, & R. Collier (CEA)
- W-P15 Target Alignment Process on the LIL Target Chamber
E. Nolot, & B. Cathala (CEA, France)
- W-P16 ISO 9001 in the Research Environment
*C.O. Russell, D.G. Schroen, D.L. Tanner, & S.L. Dropinski
(Schafer Corporation & Sandia National Laboratories/New Mexico)*
- W-P17 High Resolution Neutron Pinhole Fabrication
*P.L. Gobby, F.P. Garcia, P.M. Brooks, R.C. Snow and E.V. Armijo
(Los Alamos National Laboratory)*
- W-P18 Techniques for Assembling Capsules with Fill Tubes in NIF Scale Hohlraums
*J. Burmann, R. Jones, J. Moody, & J. Sanchez
(Schafer Corporation & Lawrence Livermore National Laboratory)*
- W-P19 The Megajoule Laser Cryogenic Target Assembly: Functions and Developments
Ph. Baclet, S. Bednarczyk, H. Bourcier, R. Botrel, O. Breton, S. Charton, R.

*Collier, E. Fleury, O. Legaie, D. Mary, G. Moll, M. Theobald, & B. Reneaume
(CEA, France)*

WORKING DINNER 6:00 – 9:00 PM (Long House Ballroom) Tom Bernat (Chair)

- Larry Foreman Award

W-16

- Target Fabrication: A View from the Users (Presented by Mike Sorem)

*George A. Kyrala, Steven H. Batha, Paul Keiter, Dennis Paisley, Jim A. Cobble,
Damian Swift, Jonathan Workman, Cindy Christensen, Nicholas Lanier, Jim
Fincke, & Matt Balkey (Los Alamos National Laboratory)*

- Other Business

THURSDAY, JUNE 5, 2003

7:30 – 8:00 AM

(Terrace Room)

Continental Breakfast

ORAL SESSION I 8:00 – 9:50 AM (Long House Ballroom) Rick Stephens (Chair)

8:00 AM Announcements

8:10 Th-1 Cryogenic Target Characterization at LLE - A Status Report

*W. Seka, A. Warrick, M.D. Wittman, R.S. Craxton, L.M. Elasky, D.R. Harding,
R.L. Keck, M. Pandina, & T.G. Brown
(Laboratory for Laser Energetics, Lawrence Livermore National Laboratory, &
The Institute of Optics, University of Rochester, NY)*

8:30 Th-2 Recent Advances in Image Processing, and Analysis of Solid DT Surface
Characteristics for DT Layers Produced in Spherical, Cylindrical and Toroidal Cell
Geometries

J. Sheliak (General Atomics)

8:50 Th-3 A Shadowgraphic Analysis Procedure for Cryogenic Layer Characterization

*A.L. Warrick, W. Seka, J. Moody, D. Bittner, L.M. Elasky, B. Kozioziemski,
& L. Iwan
(Lawrence Livermore National Laboratory & Laboratory for Laser Energetics)*

9:10 Th-4 A Model for the Characterization of the DT Layer of ICF Targets by Backlit
Shadowgraphy

*Lamy F., Pascal, G. (CEA); Mayollet L. (O++ company 31 rue de la Fonderie
BP 2000 59203 Tourcoing); Voisin Y., Diou A. (LE21 Universite de Bourgogne
IUT Le Creusot 71200 Le Creusot)*

9:30 Th-5 3-D Reconstruction of Spherical ICF Target Inner Surfaces Using Optical Backlit
Shadowgraphy

*Andrey I. Nikitenko, & Sergey M. Tolokonnikov
(Lebedev Physical Institute of the Russian Academy of Sciences, Russia)*

9:50 Th-6 Solid DT Studies in Support of Inertial Fusion Energy

*James K. Hoffer, Drew A. Geller, & John D. Sheliak
(Los Alamos National Laboratory & General Atomics)*

10:10 Coffee Break

ORAL SESSION II 10:30 – 11:50 AM Jim Kaae (Chair)

10:30 Th-7 Precision Manufacturing of Double Shell Laser Targets

R.L. Hibbard, M.J. Bono, Carlos Castro, Don W. Bennett

		<i>(Lawrence Livermore National Laboratory)</i>
10:50	Th-8	Cutting Tool Selection and Tool Life When Micromilling Rolled High Purity Gold <i>E. Giraldez (General Atomics)</i>
11:10	Th-9	Techniques for Fabricating the Window Saddles of NIF Cryogenic Hohlräume <i>E. Giraldez & J.L. Kaae (General Atomics)</i>
11:10	Th-10	Production and Metrology of Cylindrical Inertial Confinement Fusion Targets with Sinusoidal Perturbations <i>Matthew M. Balkey, Robert D. Day, Steven H. Batha, David Sandavol, Alex Sohn, & Ken Garrard (Los Alamos National Laboratory & North Carolina State University)</i>
11:50		ADJOURN

Monday

Oral Session

The Research Program for the LMJ Cryogenic Target : Main Results and Prospects

Ph. BACLET, F. BACHELET, S. BEDNARCZYK, R. BOTREL, H. BOURCIER, O. BRETON, S. CHARTON, R. COLLIER, E. FLEURY, C. GAUVIN, O. LEGAIE, A. LONGEAU(*) , D. MARY G. MOLL, JP PERIN(**), B. RENEAUME, G. TALABART, M. THEOBALD, F. VIARGUES(**)

CEA VALDUC - Laser Target Department

(*) CEA Le Ripault - Organic Materials Department

(**) CEA Grenoble - Very Low Temperature Department

To reach ignition on a megajoule laser facility, the indirect drive targets need to meet very severe thermal, mechanical, and dimensional specifications, coming from implosion physics designs. This paper deals with the main issues to obtain these requirements for each part of the target :

- the doped a-CH_x or a-DH_x microshell ^{1 2 3 4},
- the LMJ high DT pressure filling station design and prototyping ⁵,
- the transport cryostat design and prototyping,
- the concentric and very smooth DT layer at 18.2K,
- the target assembly fabrication ⁶,
- the specific thermal problems of the indirect drive configuration (hohlraum thermal profile, He/H₂ convection effects, He/H₂ filling,...), and the Study Filling Station (SFS) under development,

The current know-how and the research programs are presented for each of these studies.

¹ O. LEGAIE, M. THEOBALD, Ph. BACLET, J. DURAND « Comparative Study of a-CH films for Inertial Confinement Fusion Prepared with Various Hydrocarbon Precursors by RF-PECVD », Target Fabrication Meeting 99, 08-11 Novembre 1999, Catalina, Californie.

² M. THEOBALD, J. DURAND, Ph. BACLET, O. LEGAIE, « Comparative study of a-C:H films for inertial confinement fusion prepared with various hydrocarbon precursors by rf-PECVD », Journal of Vacuum Science and Technology A, Second Series, Vol. 18, N°1, Jan./Fev. 2000.

³ M. THEOBALD, Ph. BACLET, O. LEGAIE, J. DURAND « Properties of a-CH Coatings Prepared by PECVD for Laser Fusion Targets », Fusion technology, Vol. 38, July 2000, p 62-68.

⁴ M. THEOBALD, B. DUMAY, P. BACLET, « Thick GDP Microshells for LIL and LMJ Targets », 14th Target Fabrication Meeting, 15-19 Juillet 2001, West-Point, New-York.

⁵ Ph. BACLET, E. FLEURY, JP PERRIN, D. CHATAIN « The Filling Facility for the Megajoule Laser Cryogenic Targets », Target Fabrication Meeting 99, 08-11 Novembre 1999, Catalina, Californie.

⁶ Ph. BACLET, S. BEDNARCZYK, H. BOURCIER, R. BOTREL, O. BRETON, S. CHARTON, R. COLLIER, E. FLEURY, O. LEGAIE, F. LENORAIS, D. MARY, M. THEOBALD, “ The Laser Megajoule cryogenic Target assembly : functions and fabrication”, 14th Target Fabrication Meeting, West Point, New-York, 15-19 July 2001.

15th Target Fabrication Meeting

Project ORION; the next generation of high energy density physics research facilities in the UK to meet AWE needs

Abstract

In order to meet AWE's future high energy density physics programme requirements a new laser facility is planned, project ORION. This laser uniquely combines 10 'long' pulse beams with a total energy of 5kJ at the third harmonic with 2 'short' pulse beams each of power 1PW. All the beams are combined in a single chamber with the flexibility to cover a larger region of temperature and density parameter space than is possible with the long pulse or short pulse capability individually. The configuration of the long pulse beams is optimised for indirect drive target heating whilst the PW beams are arranged orthogonally and can be used for heating or diagnostic backlighting. The rationale behind the facility will be highlighted and facility design summarised to show that it meets the requirements for various potential experimental applications and configurations.

Advances in Target Fabrication at Sandia National Laboratories *

D.G. Schroen, C.O. Russell, J.E. Streit, D.L. Tanner

Schafer Corporation, 303 Lindberg Avenue, Livermore, California 945590-9511

S.C. Dropinski

Sandia National Laboratories, Albuquerque, New Mexico 87125

The advances in the Target Fabrication Lab at SNL have come in three areas: target design, target characterization and a quality system.

The experimenters at Sandia National Laboratories are innovative, creative and not prone to thinking only on schedule. This requires the Target Fabrication Lab to be very responsive, often while creating designs that have never been fielded before. I will present some of the more noteworthy designs, including foam designs. I will also show where some of the foam development is going as we try to produce the next target designs.

However, producing the target is only half of the job. Characterization and documentation are the other half. Without exacting characterization the experimenter does not know precisely what he has shot. This is especially clear in the EOS studies where the thickness of a glue bond can determine the experimental error. We have been extending our characterization capability in an effort to make each experiment as valuable as possible. This has lead to our acquiring of a radiography system and two optical profilometers, a Veeco NT3300 and a Nikon NEXIV.

Our need for quality lead us to develop a quality culture that recently matured with an ISO 9001 certification. While ISO 9001 is not a focus of this talk, it will be discussed as the foundation upon which we have built our work environment to ensure a focus on quality and documentation.

*This work was supported by the U.S. Department of Energy under Contract DE-AC03-01SF22266 and DE-AC04-94AL85000.

Recent Developments in Fabrication of Direct Drive Cylinder Targets for Hydrodynamics Experiments at the OMEGA Laser

A. Nobile, M. M. Balkey, J. J. Bartos, S. H. Batha, R. D. Day, J. E. Elliott, N. E. Elliott, V. M. Gomez, D. J. Hatch, N. E. Lanier, J. R. Fincke, R. Manzanares, T. H. Pierce, D. L. Sandoval, D. W. Schmidt and W. P. Steckle

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The hydrodynamics of imploding cylinders is being studied at the OMEGA laser. These campaigns are intended to investigate the role of Richtmeyer-Meshkov (R-M) instabilities in converging geometry. Recent emphasis has been to study the role of single mode features, random roughness, combinations of single mode features and random roughness, and isolated defects on the initiation of RM instabilities. In these experiments, cylinders with 860 μm diameter and 2 mm length are imploded by direct drive at OMEGA. Most of the lasers are used to drive the implosion, but a few beams are used to illuminate a backlighter that produces x-rays to image the cylinder implosion. Backlighters are usually arranged to radiograph the implosion along the cylinder axis, but some experiments have been performed to radiograph implosions transverse to the cylinder axis. The cylinders being imploded consist of a 25 μm thick polymer ablator. On the inner surface of the ablator and located halfway along the axis of the cylinder is a 500 μm wide Al band. Band thicknesses in the range 8-16 microns are used. CH foam with densities in the range 30-60 mg/cc fills the inside of the cylinder. A critical feature of the target is the surface feature that is placed on the band. While these targets have been fabricated for years, a number of new improvements and features have been developed in the last two years. Improvements include the use of epoxy instead of polystyrene for the ablator. This change has led to the ability to produce cylinders with more repeatable dimensions and improved production statistics. Another improvement has been the use of electrodeposited Al for the marker band. In the past, a variety of materials were used for the marker band, but recent experience with electrodeposited Al has resulted in a band that can reproducibly be fabricated in large quantities, and is capable of being diamond turned. Recent development work has focused on production of engineered surface features on the marker band. Using a fast tool servo on a diamond turning lathe, a wide range of specified surface features have been produced. We have produced randomly rough surfaces with power spectra that have constant amplitude over a wide range of wavelengths. The randomly rough surfaces were generated with a diamond tip atomic force microscope probe on the fast tool servo, where the fast tool servo position was generated with a random number generator. Single mode sine wave perturbations on the Al bands have been produced. Surface features consisting of a single mode sine wave perturbation that has random roughness superimposed on it have been produced. Isolated defects, such as grooves have also been placed on the bands. This talk will address the recent improvements to the cylinder targets as well as recent new developments.

Preferred Presentation Format – Presentation

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A review of development activities for the AWE Experimental Laser Programme

Abstract

Increasingly stringent target specifications for recent experimental campaigns and the anticipation of increased complexity for targets for the experimental programmes to be fielded on Z, ORION and NIF are driving a reorganisation of the AWE target fabrication activities. Most recent demands have been in surface characterisation and some examples will be discussed but a number of problems areas in materials processing are also expected and a review of current activities, such as polymer forming and micro-plating, is included. Some early plans for Orion experiments, which include a significant development phase, will also be discussed.

Fabrication of Fast Ignition Targets^{*}

D. Hill, A. Nikroo, J.L. Kaae, J.N. Smith, Jr., and D.A. Steinman

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Fast ignition is a novel scheme for achieving laser fusion. For recent campaigns, General Atomics has been fabricating and assembling cone mounted shells for use as fast ignition targets. Fabrication of such targets requires producing appropriate cones and shells, assembling the targets, and characterization of the assembled targets. The cones are produced using micromachining and plating techniques. The shells are fabricated using the depolymerizable mandrel technique followed by micromachining a hole for the cone. Precise alignment of the cone tip with respect to the center of the shell is a crucial step in the assembly of the target. Characterization of these targets is complicated by the presence of the cone which blocks some viewing angles and scatters light sources. This presentation gives an overview of the developmental efforts, technical issues and a range of possibilities for each fabrication step. In particular, the recent fabrication of two types of targets is discussed. The first involved gas filled targets, which were recently shot at the OMEGA laser facility. The second involved development of copper-doped plasma polymer coatings used in fabrication of copper-doped fast ignition targets for experiments at RAL.

^{*}This work was supported by the U.S. Department of Energy under Contract DE-AC03-01SF22266.

The Use of Polyimide in the Fabrication of ICF Targets

Forbes Powell

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Abstract

This paper discusses the use of polyimide in the preparation of targets for Inertial Confinement Fusion (ICF) targets. Polyimide has much higher strength and radiation resistance than similar polymer films. This allows, for example, ultra thin windows for hohlraum targets. Luxel Corporation has many years of experience in the spin casting of freestanding polyimide films in thickness ranging from 300 to 20,000 Å. These films are used to fabricate gasbags, hohlraum windows, capsule tents, and convection baffles for targets. The polyimide films can also be used as a structural backing for ultra thin metal foils.

In addition, Luxel has successfully fabricated polyimide shapes such as spherical capsules, hemispheres, and cylinders. These shapes are created by applying liquid polyamic acid using atomizer, ink-jet, or dip-coating technology. The components are then imidized to form polyimide. This technique has been successfully used to fabricate components for use in z-pinch and laser ICF targets. □

Prefer oral presentation □

Status of the Ice-Layering Development Effort at OMEGA

D. R. Harding, M.D. Wittman, L. Elasky, J. Sailor and E. Alfonso

Laboratory for Laser Energetics, University of Rochester, Rochester, NY

Abstract

Experience forming deuterium-ice layers using the OMEGA Cryogenic Target Handling System (CTHS) has provided insight into the process by which the ice layer is first formed and then smoothed. It is apparent from a large statistical sample that ice layers with a substantial low-frequency roughness—6 to 10 μm in the first two to three modes—can be stable for multiple days. Whereas at other times, ice layers approaching 2- to 3- μm smoothness over the first 20 modes are achievable. This dichotomy will be presented. The cause is critical to understanding why ice layers smoother than 2- μm have not been achieved. It is also necessary to solve this problem to routinely provide smooth ice layers for a full suite of implosion experiments.

Different processes exist for forming ice layers. There is a correlation between process and the resulting roughness of the ice; however, there is a significant variation in ice roughness associated with each process. This indicates that there remains an uncontrolled parameter that affects the ice layer. This presentation will address how well we know, and can control, critical parameters inside the layering sphere that will influence the ice layer. In its simplest form this requires knowledge of the (1) magnitude and uniformity of the heat coupled into and out of the capsule, and (2) whether our assumption that an isothermal boundary condition on the layering sphere is preserved through the gas, the plastic capsule, and the ice is correct. The ice-layering process reasonably assumes that the inner ice surface is isothermal, but if the isothermal behavior is not radially uniform along the target's polar and azimuthal angles, a variation in the thickness of the ice layer will be manifest as a low-frequency roughness in the power spectrum. This problem is currently being studied.

This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC03-92SF19460, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

Deuterium Solidification in Foam

R. Q. Gram and D. R. Harding

Laboratory for Laser Energetics, University of Rochester, Rochester, NY

Abstract

Future cryogenic targets for the OMEGA laser may contain low-density foam filled with solid deuterium. Polymer shells of 1-mm diameter will have a 100- μm -thick internal layer of foam, that becomes saturated with liquid deuterium, which is then cooled and solidified. Likewise, flat targets with cylindrical foam-filled cavities of 1-mm diameter and 1-mm thickness covered with windows of polymer or thin Al_2O_3 will be filled from tubes with liquid deuterium, which is then cooled and solidified. Because deuterium contracts upon solidification, voids can be created in the foam. The transparency of the foam during the solidification process yields information on these voids and how to avoid generating them. The impact of transparency on characterizing layer uniformity is considered.

This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC03-92SF19460, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

Modeling Temperature and Pressure Gradients During Cooling of Thin-Walled Cryogenic Targets

E. L. Alfonso, R. Q. Gram, and D. R. Harding

Laboratory for Laser Energetics, University of Rochester, Rochester, NY

ABSTRACT

Cooling thin-walled capsules filled with deuterium is a critical phase of operation for providing cryogenic direct-drive targets. During cooling to 20 K, buckling and burst forces develop due to transient thermal gradients, thermal expansion differences in the materials of the capsule and permeation cell, and changing permeability of the plastic. This article presents the results of both a steady-state and a transient analysis of the pressure differences across the wall of a thin-walled capsule during the cooling process. The steady-state contribution to the pressure difference arises from two sources: (1) the different thermal contractions of the materials that comprise the permeation cell and capsule and (2) the room-temperature volume of gas in the line connecting the permeation cell to the isolation valve. The transient analysis considers the pressure differences across the capsule wall that arise from the changing temperature gradients within the gas during the cooling cycle. Both effects have been taken into account to determine the approach required to produce fuel-filled thin-walled cryogenic targets more rapidly. Currently, capsules are slowly cooled at a rate of 0.1 K/min to prevent their destruction. This process requires over 45 h to complete. The results of the present model present a faster cooling program that takes into consideration the induced pressure differences, permeation occurring at higher temperatures, and the strength of the capsule. The time to cool a filled target can be reduced by 25% while maintaining capsule survival.

This work was supported by the U. S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC-03-02SF19460, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute endorsement by the DOE of the views expressed in this article.

Update on Ignition Target Designs for NIF

Steve Haan

Lawrence Livermore National Laboratory

Abstract Not Submitted

RECENT PROGRESS IN 2-MM-DIAMETER NIF MANDREL PRODUCTION

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Masaru Takagi, Robert Cook
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All planned National Ignition Facility (NIF) capsule targets except machined beryllium require a plastic mandrel upon which the ablator is applied. This mandrel must at least meet if not exceed the symmetry and surface finish requirements of the final capsule. The mandrels are produced by a three-step process. In the first step a thin-walled poly(α -methylstyrene) (P α MS) shell is produced using microencapsulation techniques. This shell is then overcoated with 10 to 15 μ m of glow discharge polymer (GDP). The final step is pyrolysis at 300 °C to depolymerize the P α MS to gas phase monomer that diffuses away through the more thermally stable GDP shell. The quality of the final GDP shell depends upon precise optimization and execution of each of the three steps. In the past year we have focused upon converting the feasibility that we have previously demonstrated into a high yield, production scale process. We will discuss recent progress towards this objective as well as the prospect of using these techniques to produce full thickness GDP NIF capsules.

This work was performed under the auspices of the U.S. Department of Energy by the University of California Lawrence Livermore National Laboratory under contract W-7405-Eng-48 and by General Atomics under contract DE-AC03-95SF20732.

PROGRESS TOWARD MEETING NIF SPECIFICATIONS FOR VAPOR DEPOSITED POLYIMIDE ABLATOR COATINGS

Stephan Letts, Mitchell Anthamatten, Steven Buckley,
Evelyn Fearon, April Nissen, Robert Cook

Lawrence Livermore National Laboratory
Livermore, CA 94550

We are developing an evaporative coating technique for deposition of polyimide (PI) ablator layers on ICF targets. We use plasma polymer shells prepared by the depolymerizable mandrel technique as a substrate mandrel. The PI coating technique utilizes stoichiometrically balanced fluxes from Knudsen cell evaporators containing the two reactive monomers (pyromellitic dianhydride, PMDA and 4, 4' oxydianiline, ODA) to first make a polyamic acid (PAA) coating. Heating the PAA coating to 300°C converts the coating to a polyimide. Roughness in the PAA layer has been a problem due to abrasion effects from the agitation needed to maintain a uniform coating and small particulate contaminants on the mandrel. We have developed a smoothing process that exposes an initially rough PAA coated shell to solvent vapor using gas levitation. Solvent absorption by the PAA layer results in surface tension driven flow of the bumps and a reduction in roughness. We are now able to deposit coatings 160 μm thick with a surface finish of better than 20 nm RMS. AFM sphere mapping indicates that smoothed PI coatings are as good as the mandrel. The yield of shells meeting NIF specifications has improved by minimizing air exposure, which tends to hydrolyze the polyamic acid coating. We will discuss the operation of the coating system and various methods used to prevent sticking and reduce damage due to agitation.

This work was performed under the auspices of the U.S. Department of Energy by the University of California Lawrence Livermore National Laboratory under contract W-7405-Eng-48.

Monday

Poster Session

Target Insertion Cryostat Design Concepts for the NIF Cryogenic Target System*

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The concept for the NIF Cryogenic Target System has been modified to utilize a separate cryogenic target positioner (C-TARPOS), rather than the room temperature Target Positioner (TARPOS). The concept for the C-TARPOS will allow rear entry of the Target Insertion Cryostat (TIC). Design concepts for the TIC to take advantage of this configuration of the C-TARPOS will be presented.

*This work was supported by the U.S. Department of Energy under Contract DE-AC03-01SF22266.

MK-1 Closed Cycle Cryostat*

(Poster Session)

R. Frazee¹, T. Bernat², V. Brugman², A. Debeling², B. Haid², J. Stewart¹

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The Mk-1 cryostat will serve as a low cost, fast track target fielding device to be installed at the National Ignition Facility (NIF) prior to the Mk-1 flow cryostat target insertion system. Only room temperature targets will be mounted on the Mk-1. However, after the NIF target positioning boom (TARPOS) is evacuated, the Mk-1 has the ability to cool targets to cryogenic temperatures and accurately position them at target chamber center (TCC). The Mk-1 closed loop cryostat design is based on cryogenic target cryostats currently in use at the University of Rochester, Laboratory for Laser Energetics.

* Work supported by U.S. Department of Energy under Contracts DE-AC03-01SF22260 and W-7405-ENG-48.

A Comparison of Liquid Helium-Based and Cryocooler-Based Target Cryostat Designs*

(Poster Session)

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This presentation compares two target cryostat designs that are being considered for near-term cryogenic target fielding at the National Ignition Facility (NIF). The first design[†] utilizes the cooling afforded by a liquid helium stream that flows from a reservoir at the end of the target positioner (TARPOS). This design is being developed in collaboration with CEA-SBT in Grenoble, France. The second design[‡] is based on a system currently used to field planar targets at the Laboratory for Laser Energetics in Rochester, NY. Refrigeration is provided by a closed-cycle cryocooler in this system.

The major differences in developmental tasks and operational procedures between the two designs are identified. Thermal performance expectations are compared based on the simulated results of finite-difference models. Target positioning accuracy is also discussed.

The liquid helium system offers higher refrigeration power, lower temperatures, faster cool-down, and better target positioning accuracy. The cryocooler system offers faster and cheaper development, simpler operational procedures, and a virtually infinite hold time. The cryocooler system's thermal performance and positioning accuracy is sufficient for fielding a variety of cryogenic targets. We are evaluating the possibility of building a cryocooler system to expedite early fielding of cryogenic targets while awaiting completion of the liquid helium system.

* Work supported by U.S. Department of Energy under Contracts DE-AC03-01SF22260 and W-7405-ENG-48.

† J. Stewart, T. Bernat, V. Brugman, A. Debeling, R. Frazee, L. Guillemet, B. Haid, J. Perin, F. Viargues, "MK-1 Liquid Helium Flow Cryostat", presented at this conference.

‡ R. Frazee, T. Bernat, V. Brugman, A. Debeling, B. Haid, J. Stewart "MK-1 Closed Cycle Cryostat", presented at this conference.

High Pressure Deuterium Fill System

J. Pipes, and J. Sater

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The deuterium test system, a collaborative effort between General Atomics and Lawrence Livermore National Laboratory, studies methods of producing cryogenic fuel layers in hohlraums without fill tubes for the National Ignition Facility. This experiment prototypes high pressure permeation filling, target cooling and the components required to deliver cryogenic ignition target to NIF. We have constructed and are operating a high pressure deuterium system to accurately permeation fill capsules in fully assembled hohlraums to 6,000 PSI without damaging their fragile components. This presentation will describe the components, operation and results of this system.

This work was performed under the auspices of the U.S. Department of Energy by the University of California Lawrence Livermore National Laboratory under contract W-7405-Eng-48.

Mark-1 LIQUID HELIUM FLOW CRYOSTAT*
(Poster Session)

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The Mark-1 pre-ignition cryostat will serve as the target fielding device at the National Ignition Facility (NIF) prior to a target delivery system capable of handling cryogenic ignition targets. Targets will be mounted on the Mark-1 only at room temperature, and subsequently cooled to any temperature between ambient and a minimum of 5 K. The Mark-1 will cool the targets after the NIF target positioning boom (TARPOS) is evacuated, after which the targets are accurately positioned at target chamber center (TCC). A shroud capable of being cooled covers the target to prevent condensation of residual target chamber gasses, and to limit the radiant heat load on the target. The shroud is opened just before the shot, with a minimum opening time of 1 second. The Mark-1 liquid helium flow cryostat design is the result of LLNL collaboration with CEA-SBT in Grenoble, France.

* Work supported by U.S. Department of Energy under Contracts DE-AC03-01SF22260 and W-7405-ENG-48.

Effect of Low Mode Defects in PAMS Shells on Thick and Thin GDP Shells Made Using the Depolymerizable Technique*

A. Nikroo, J.B. Gibson, and E. Castillo

General Atomics, P.O. Box 85608, San Diego, California 92186-5608

A large fraction of polymer shells currently used in ICF experiments are made using the depolymerizable mandrel technique. The quality of the final glow discharge polymer (GDP) shell naturally depends on the surface finish of the poly-alpha-methylstyrene (PAMS) shells used as starting mandrels. However, coating and pyrolysis steps could add additional defects that might overshadow those of the mandrel. We have examined the effects of these processes on the low mode surface finish of GDP shells. Both thin and thick GDP shells were examined, particularly at the 1 mm diameter size used for direct drive OMEGA experiments. PAMS shells with and without \sim mode 10 wrinkling were used for this study. Presence or absence of such low mode defects were faithfully replicated in thick GDP shells. However, for thin GDP shells, low mode wrinkling was induced during pyrolysis even when using smooth PAMS mandrels.

*This work was supported by the U.S. Department of Energy under Contract DE-AC03-01SF22266.

Fabrication Techniques and Properties of Overcoated Resorcinol-Formaldehyde Foam Shells*

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Resorcinol-formaldehyde (R/F) shells have been fabricated using microencapsulation for use at the OMEGA facility. Fabrication techniques used in obtaining concentric shells (>95%) in density range of 100–150 mg/cc are discussed along with batch statistics. The R/F foam shells have been overcoated with permeation seal coatings deposited by two methods. In the first method, plasma polymer is coated directly on the R/F shells. In the second method, R/F shells are coated using a chemical interfacial polymerization technique. Properties of the overcoated shells important to target performance are gas retention, strength, and surface finish. The results of property measurements for each overcoated target system are presented. Comparison of the property measurements for each system are discussed with the goal of producing an optimum target for use at OMEGA.

*This work was supported by the U.S. Department of Energy under Contract DE-AC03-01SF22266.

A SPECTROSCOPIC STUDY OF CURING OF VAPOR-DEPOSITED POLY(AMIC ACID)

Mitchell Anthamatten, Katherine Day, Stephan A. Letts, Steven Buckley,
Evelyn Fearon, April Nissen, Robert C. Cook
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Fourier-transform infrared spectroscopy was used to study curing in vapor-deposited (ODA/PMDA) polyimide films. Film samples were mounted into a custom-built temperature-controlled IR cell. The conversion of anhydride functional end-groups to amide linkages was observed at temperatures between 50 and 125 C. At temperatures above 150 C, all amide linkages disappeared upon forming thermally stable, 5-member imide linkages. Our results indicate that the solid-state polymerization continues prior to forming thermally stable imide linkages—this is not observed in films prepared using traditional solution-cast methods. We are currently using visible spectroscopy, MALDI-TOF spectroscopy, and thermal techniques to further study this reaction.

This work was performed under the auspices of the U.S. Department of Energy by the University of California Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

OXYGEN UPTAKE BY PLASMA POLYMER MATERIALS

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One of the capsule ablator options for ignition experiments at the National Ignition Facility is plasma polymer. Plasma polymer coating is produced by flowing hydrocarbon feed gas and hydrogen through an inductively coupled plasma generator. The hydrocarbon gas is fragmented by electron impact in the plasma. The reactive fragments subsequently recombine downstream as a polymer film on shell mandrel substrates. The empirical formula of the produced materials is typically $\text{CH}_{1.3}$, or a similar deuterated analog if fully deuterated materials are used. The addition of small amounts of tetramethyl germane to the flow gas results in a Ge-doped material at levels up to a few atom %. It has been long known, however, that these materials react slowly with ambient oxygen to produce $\text{CH}_{1.3}\text{O}_x$, or the deuterated analog, where x is both time and environment dependent. Recent work has shown that this O uptake is accelerated in the presence of the Ge dopant. Not only is the composition changed by the addition of O, but also the density of the material. Both composition and density are critical parameters in ignition implosion physics, and the objective of this work is to quantify the time and exposure dependence of the compositional and density changes in NIF scale plasma polymer ablator capsules. A variety of studies have been carried out to measure these changes and results to date will be reported.

This work was performed under the auspices of the U.S. Department of Energy by the University of California Lawrence Livermore National Laboratory under contract W-7405-Eng-48 and by General Atomics under contract DE-AC03-95SF20732.

Progress with AFM Spheremapping: Noise Reduction and Coverage Improvement^{*}

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Since Target Fabrication Specialist Meeting 14, General Atomics has replaced their Spheremapper's Atomic Force Microscope with a new one from Digital Instruments. After this was accomplished we discovered that the noise threshold was unacceptably high. Since then we have added the capability for near-real-time noise measurements and, using that capability, identified and minimized several noise sources. The result of this effort has been to reduce the noise power by more than three orders of magnitude, much less than it was in the original setup. Our method for determining the inherent signal fluctuations is discussed as well as identification and elimination of sources.

We have also added the capability for AFM Spheremapper profiles far from the shell equator. This allows substantial improvement in shell coverage, allowing a much more accurate representation of the shell surface. An example is presented of a mapping of a 2 mm shell by making closely spaced parallel traces over a 320 μm band for five different shell orientations and the projection of the data onto a sphere. This mapping puts over 60% of the shell within 20 μm of a trace.

^{*}This work was supported by the U.S. Department of Energy under Contract DE-AC03-01SF22266 and a DOE National Undergraduate Fusion Fellowship.

Full-wave and ray trace calculations of shadowgrams compared with measurements

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We describe initial comparisons between measured shadowgrams and shadowgrams calculated using two different theoretical approaches. In one approach we perform a full-wave calculation of the forward scattered light from a monochromatic collimated beam incident on a layered cylinder. The scattered light is collected with a perfect imaging system having a specified $f/\#$ and a second calculation determines the desired shadowgram. We observe diffraction effects at hard edges and find that the bright band shows interference structure in some cases. In the other approach we perform a detailed ray trace calculation and image the transmitted rays with a perfect imaging system having a prescribed $f/\#$. This allows us to carefully track the origin of each feature in the resulting shadowgram. We use this method to investigate the effects of focus variation, optical index variation, dispersion, and realistic optical systems. Both calculations are compared with real shadowgram measurements for various kinds of layered spherical targets. We describe the details of the two calculation methods and show comparisons between the methods and the measurements. Reasons for the similarities and differences are discussed.

This work was performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

Automated Batch Shell Characterization*

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We have installed an automated measuring microscope (Nikon VMR-3020) for batch measurements of plastic shells. Its accuracy is good enough to replace the existing tools for PAMS shell measurement. Its particular value is in making unattended batch measurements. In that case, the shells are mounted onto a rectangular array of drilled holes on a flat substrate. It takes about 15 minutes to fully characterize 20 Omega-sized shells (once) using a **Detailed** measurement routine, which can be programmed to conduct repeated measurements overnight. For production screening of OD and circularity, 20 shells can be characterized (once) in less than one minute using a **Quick** measurement routine. The microscope reduces the focusing error due to manual operation and allows direct visualization of the shell wall. So far we have successfully characterized shells made of PAMS, GDP, glass, and foam materials, as well as the fast ignition shells mounted on gold cone. The instrument requires pristine shell surface for good repeatability and is limited to the overall wall thickness if a multilayered shell is measured.

*This work was supported by the U.S. Department of Energy under Contract DE-AC03-01SF22266.

Evolution of ICF Target Technology^{*}

W.J. Miller and the GA/Schafer ICF Target Support Team

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Since ICF is an experimental research and development program, the designs and specifications for targets change over time. Over the past ten years, ICF target technology has evolved considerably in the areas of coatings, foams, micromachining, capsules, planar targets, cryogenic engineering, and cryogenic DT and D₂ layering. We will present a graphic display of the evolution.

^{*}This work was supported by the U.S. Department of Energy under Contract DE-AC03-01SF22266.

Recent Developments in Fabrication of Double Shell Targets for Experiments at the OMEGA Laser

A. Nobile, J. J. Bartos, R. D. Day, N. D. Delamater, J. E. Elliott, N. E. Elliott,
V. M. Gomez, D. J. Hatch, G. A. Kyrala, R. Manzanares, T. H. Pierce,
D. L. Sandoval, D. W. Schmidt and W. P. Steckle

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Double shell targets represent an alternative approach to the cryogenic ignition target. Experimental campaigns are being conducted with double shell targets at the OMEGA laser. In recent campaigns, a number of improvements have been implemented in fabricating these targets. A significant improvement has been the change in the outer ablator material from polystyrene to epoxy. The outer ablator is produced by machining a copper mandrel to the desired hemispherical shape, followed by deposition of the ablator material onto the mandrel. The ablator material is then machined, and the mandrel is leached with nitric acid. The new epoxy ablators have been shown to be reproducible, have very little shrinkage and have resulted in fewer reject components. Another improvement has been the development of an interference joint for the outer hemishells that eliminates the use of glue in the joint. Glue in the hemispherical joint can influence the implosion, so eliminating the use of glue has been a significant improvement. The outer hemishells are produced with a male and female step joint. A carefully designed interference fit between the male and female hemishells allows the targets to be held together without glue. Targets fabricated with these joints have been successfully made and fielded at OMEGA. A recent development has been the incorporation of a 6 μm thick sulfur-doped epoxy marker layer on the inner surface of the outer hemishells. Multiple epoxy depositions were performed to produce this marker layer. Recent double shell campaigns have involved direct drive implosions at OMEGA. These targets have diameters in the range 900-950 μm . Inner capsule diameters were approximately 450 μm in diameter. CH foam is placed between the outer ablator and the inner capsule. Foams with densities in the range 30-120 mg/cc have been used. Static radiographs of the targets have demonstrated centering of the inner capsule to within 5 μm . Another development has been the assembly of this target with multiple (two) backlighters for obtaining orthogonal images of the target during implosion. In a recent OMEGA campaign, successful images were obtained from double shell target implosions, demonstrating the use of the double backlighter arrangement. To improve the diagnosing of double shell targets, we have been examining the use of micro computed tomography (CT). We have shown that micro CT images obtained from a commercially available instrument can provide useful information about these targets. This poster will describe the recent improvements and developments in double shell targets.

Preferred Presentation Format – **Poster**

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High Precision x-radiography for characterization of NIF targets

R.B. Stephens (General Atomics) and G. Flint (Photera)

The x-ray opacity of NIF shells is required to vary by less than $1:10^4$ averaged over $(100\text{ }\mu\text{m})^2$. Such precision is beyond the capability of any existing radiograph film or imaging plate system. Astronomers, in their quest to detect planets near stars, have developed and demonstrated an approach that reduces systematic and shot noise to the 10^{-5} level. The basic requirements are that 1) every detector spend equal time viewing every part of the sample, and 2) one counts $>10^8$ photons at every part of the image. The first eliminates systematic noise, the second the shot noise. The device built for this purpose is presently unused, and could be reconfigured into a radiograph system with modest effort. Details of this setup will be presented.

Cryogenic Pressure Loader Report: D₂ Target Filling and DT Leak Testing

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John D. Sheliak, General Atomics/Los Alamos National Laboratory.

The Cryogenic Pressure Loader (CPL) project at Los Alamos National Laboratory is a permeation fill system and cryostat for performing Deuterium-Tritium (DT) filling and layering research on polymeric ICF capsules without fill tubes. The CPL system is housed within a glovebox in the Los Alamos tritium facility. Following target filling, the cryostat which houses the high-pressure permeation cell can be cooled to cryogenic temperatures before the DT overpressure is removed and the target withdrawn from the permeation cell. The beta-decay driven layering process ("beta-layering") of the cryogenic solid DT in the target shell can be observed through windows in the cryostat. The CPL shares common design elements, including the permeation cell, with the University of Rochester's Cryogenic Target Handling System (CTHS), supplied by General Atomics. The CPL also follows the same basic operational principles for target filling as are used by LLNL's D2TS system, and will be used by the proposed DT target fill systems to be used at the National Ignition Facility and the Laser Mega Joule. Layering research performed on the CPL will investigate issues involved with beta-layering DT layers inside capsules with no fill tubes. The ability of the CPL to rotate capsules may be exploited to investigate the influence of asymmetries of the layering environment on layer uniformity. With some modification the CPL will be able to perform layering and thermal studies on targets within hohlraums. In March 2001 the CPL glovebox was closed up for the commencement of deuterium testing. Two successful fill cycles have been performed with deuterium; filling polymer shells to ~200 atmospheres; cooling them, and observing solidification of the D₂ ice. Leak testing of the system with low concentrations of tritium in deuterium has begun. In this report the current status and future plans of the CPL will be presented.

This work is performed at Los Alamos National Laboratory and supported by the U.S. Department of Energy under contract number W7405-ENG36. LA-UR-03-1909.

Oral Presentation Preferred

FIRST RESULTS ON THE CRYOTARGET POSITIONER PROTOTYPE FOR THE LASER-MEGAJOULE

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The Laser Megajoule cryotarget positioner will be used to place the cryogenic targets at the center of the experimental vacuum vessel. It will consist of a 6 meters carbon boom at the end of which a target will be held by a cryogenic gripper at 20 K. In the French concept, the targets will be transferred at 20 K to the cryotarget positioner from another cryostat. Then, some of the specifications are very drastic. Indeed, the targets must be positioned with a high precision ($\pm 5\mu\text{m}$), the temperature must be controlled with a very good stability and the cryostat must have a 5 days of autonomy. To cope with these requirements, some technical solutions have been considered. To validate these choices, a scale one prototype (cryostat Echelle 1) has been studied and built at the Low Temperature Laboratory (SBT) of the CEA/Grenoble (France). First results have been obtained. With a liquid helium flow rate of 2.1 l/h corresponding to the natural heat load, the temperature of the gripper was 10.7 K. The next step is to demonstrate that the target can be caught and kept cold. For this an hexapod will be used. It will run before the end of 2003.

A description of the prototype will be done. Some results in term of heat load, autonomy and thermal regulation will be given. This work is supported by the CEA/LMJ program.

NUMERIC MODELING OF OPTICAL IMAGES OF SPHERICAL ICF TARGETS

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The use of backlit shadography, optical interferometry, and X-ray imaging are well known methods of ICF spherical target characterization. To better understand the various image details and to correlate them with geometric features of the target we have developed a 3-D numerical ray-trace model and related software package. This model can be used for the study of transparent multi layer shell images including ICF targets with an internal solid hydrogen fuel layer. The model assumes a collimated backlit image and does not take into account diffraction, polarization, or dispersion. Each layer (be it the shell or fuel) is assumed optically homogeneous. Shadowgraph images as well interferometric and X-ray images can be produced with the PC-compatible software package based on this model. Various combinations of light direction and image plane position can be utilized. In addition the software can generate intensity profiles along vertical or horizontal diameters of the object, as well as show the trace path of any incident ray. In this presentation we include the description of the model and software package. Model and software package validation is demonstrated with a comparison of simulation images with those obtained experimentally. We will be using this package to analyze experimental data collected on cryogenic layers.

Part of this work had been carried out under the support of the International Science and Technology Center (ISTC project #1557).

Tuesday

Oral Session

**Progress in Direct-Drive Inertial Confinement Fusion Research at the
Laboratory for Laser Energetics**

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The primary mission of the Laboratory for Laser Energetics (LLE) at the University of Rochester is to study all aspects of direct-drive ICF with the ultimate objective of achieving direct-drive ignition on the National Ignition Facility (NIF).

LLE's baseline direct-drive ignition design for the NIF is an "all-DT" design with a 1-D gain of ~ 45 . Recent calculations show that targets composed of foam shells, wicked with DT, can potentially achieve 1-D gains ~ 100 . Current target design research includes exploring the use of adiabat shaping and the possibilities of performing direct-drive ignition experiments in NIF's x-ray drive configuration [Polar Direct Drive (PDD)].

LLE's experiments are conducted on the 60-beam, 30-kJ, UV OMEGA laser system. Beam-smoothing techniques on OMEGA include 1-THz, 2-D smoothing by spectral dispersion (SSD) and polarization smoothing (PS). Cryogenic D₂ and plastic-shell (warm) spherical targets and a comprehensive suite of x-ray, nuclear, charged-particle, and optical diagnostics are used in these experiments.

This talk will review recent theoretical and experimental progress in direct-drive ICF at the University of Rochester.

This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC03-92SF19460, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

Overview of Foam Shell Fabrication for Use at LLE's OMEGA Facility*

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Currently, experiments are underway at the University of Rochester's OMEGA facility to test the viability of direct drive NIF designs using foam shells. At General Atomics we have been developing and fabricating such shells in the ~ 1 mm diameter, 50–100 μm wall thickness and 90 < mg/cc ranges for the experiments at OMEGA. Resorcinol-formaldehyde (R/F) aerogel, which due to its small cell size ($\lesssim 100$ nm) is transparent in the visible regime, has been chosen as the foam material for these shells. Foam shells in the 800-1200 μm diameter range have been produced. Extensive characterization of the wall uniformity of these shells has been performed. These foam shells have $\sim 5\%$ – 6% non-concentricities on the average. A permeation seal, which is essential for gas retention, has been deposited on RF shells using two different techniques. In the first technique R/F shells are coated directly with plasma polymer to thicknesses ≈ 3 – 4 μm . In the second technique, R/F shells are coated using the chemical interfacial polymerization technique. An overview of shell properties such as surface finish, gas retention and structural changes to the foam due to the coatings are discussed.

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Marangoni Instabilities in Microencapsulation^{*}

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Hollow spherical shells used as laser targets in inertial confinement fusion experiments are made by microencapsulation. During the final phase of manufacturing, the spherical shells contain a solvent (fluorobenzene, FB) and a solute (polystyrene, PAMS) in a water environment. As the solvent evaporates it leaves behind the desired hardened plastic spherical shells, 1-2 mm in diameter. Perfect sphericity is demanded for efficient fusion ignition. We model this drying process and investigate conditions for incipient Marangoni instabilities driven by surface tension dependence on concentration (buoyant forces are negligible in this micro-scale problem). For the moving-boundary, diffusive state solution, we assume zero fluid velocity and solve for the concentration of the FB, using a second-order finite volume approach and Crank-Nicholson time marching. The inner radius of the shell is taken as impermeable and non-linear boundary conditions are specified at the receding outer boundary. This diffusive state might lose stability through the Marangoni mechanism. We are concerned with the limit of small Capillary number, which is a measure of the deviation of surface tension from its average value and thus the magnitude of surface deflection. Moreover, to lowest order in this limit, the outer surface is determined by the diffusive solution. Linear stability analysis assuming normal mode decomposition in surface harmonics with radial velocity and concentration perturbations determines the Reynolds number (Re) of the critical state. A frozen-time, or quasi-steady-state analysis, was done employing pseudo-spectral and shooting techniques. For the 1 mm shells, at all times during the drying process, the critical Re always corresponds to mode 1. However, for the 2 mm shells, it was found that at early times of the drying process we have mode 1 ripples while higher modes are preferred at later times. This is consistent with experiments where lowest modes exhibit largest amplitudes, as these are the modes dominating at early times and are expected to persist due to exponential increase of viscosity as drying proceeds. Moreover, the experiments with the 2 mm shells correspond to Re values much lower than critical, due mainly to highly viscous initial states, precluding Marangoni instabilities. Operating conditions for the 1 mm shells evaluated at somewhat uncertain property values, are at Re much closer to the theoretically predicted critical values. Thus the 1mm shells are susceptible to surface bumps caused by Marangoni instabilities. These results are also consistent with experiments.

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Particulate Doping of TPX Foams*

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TPX foam is the most requested foam for use on the Z accelerator at Sandia National Laboratories. Requests for foam targets have recently expanded to include CH foams with dopants. TPX foam can be made at low densities and techniques have been developed to “dope” these foams with particulate matter. We have been using nanopowders in an attempt to get uniform distributions and small dopant particle sizes. We characterize the bulk dopant uniformity by radiography and the particulate size using SEM. The foam production technique started with non-uniform dispersion of large agglomerations of particulates. Techniques have improved to produce uniform foams and experiments are underway to provide foams with as little agglomeration as possible. This presentation will describe the ground that has been covered and the development that is currently underway

*This work was supported by the U.S. Department of Energy under Contract DE-AC03-01SF22266.

15th Target Fabrication Specialists Meeting

Characterisation of Particulate Loaded Low Density Polymer Foams

Abstract

An overview of research on the development, production and particularly the necessary characterisation of particulate loaded low-density polymer foams in support of the AWE plasma physics experimental programme. It encapsulates work done both at AWE and under extramural contract at Dundee University. The techniques used for the characterisation of the polymer foams, Environmental Scanning Electron Microscopy (ESEM), Point Projection Microradiography and White light Interferometry, will be detailed along with a background discussion on the foam production technique. Future direction of the characterisation techniques and recommendations for further work are also discussed.

Status of Polyimide Target Development Activities at LLE

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Abstract

Previous research efforts to fabricate direct-drive polyimide shells have focused on identifying processes that maximize the mechanical and permeation properties of the polyimide material.¹ A strong correlation exists between these properties and the processing conditions, which is ascribed to the crystallinity and segmental mobility of the polyimide chains. This correlation, together with the range of properties that have been demonstrated, will be presented.

Current research efforts focus on improving the smoothness of the polyimide shells. The approach is to model the effect of different configurations of the equipment and processing parameters on the impinging mass flux of reactants onto the shell substrates. This is done using both computational fluid dynamics (FLUENT) and Monte Carlo codes to cover the relevant pressure regimes. Both molecular gas dynamics and surface chemistry are included in the models. These models are then cross-referenced to the measured smoothness of the shells.

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References

1. See National Technical Information Service Document No. DOE/SF/19460-465 [Laboratory for Laser Energetics LLE Review **92**, 167 (2002)]. Copies may be obtained from the National Technical Information Service, Springfield, VA 22161.

**ORIGIN AND EVOLUTION OF STRUCTURED AMORPHOUS FILMS
PREPARED BY GLOW DISCHARGE POLYMERISATION FOR ICF EXPERIMENTS.**

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For the next “Mégajoule” Laser (LMJ) facility of the cea, amorphous hydrogenated carbon (a-C:H) is the nominal ablator to be used in French inertial confinement fusion (ICF) experiments. These capsules contain the fusible deuterium-tritium mixture to achieve ignition. Coatings are prepared by glow discharge polymerization (GDP) with trans-2-butene and hydrogen. The films properties have been investigated. Laser fusion targets must have optimized characteristics : a diameter of about 2.4 mm for LMJ targets, a thickness up to 175 μm , a sphericity and a thickness concentricity better than 99% and an outer and an inner roughness lower than 20 nm at high modes. The surface finish of these laser fusion targets must be extremely smooth to minimize hydrodynamic instabilities.

Movchan and Demchishin, and after Thornton introduced a structure zone model (SZM) based on both evaporated and sputtered metals. They investigate the influence of base temperature on the condensation and the sputtering gas pressure, on structure and properties of thick polycrystalline condensation of nickel, titanium, tungsten, aluminum oxide. An original cross-sectional analyze by atomic force microscopy characterizes these amorphous materials and permits to make an analogy between the GDP material and the existing model (SZM). The purpose of this work is to understand the relationship between the deposition parameters, the growing structures and the surface roughness.

The parametric is first realized on plane silicon substrate and the optimized on PAMS shells. By adjusting the parameters and the structures, the background roughness decreases dramatically.

EXPERIMENTS AIMED AT UNDERSTANDING SOLVENT-VAPOR SMOOTHING OF POLYMER SURFACES

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In the interest of fabricating NIF quality polyimide laser fusion targets, we are studying a post-deposition solvent-vapor smoothing procedure. Our approach is to temporarily swell the polymer coating with solvent molecules. As the solvent penetrates into the polymer, the coating viscosity is lowered, and surface tension drives flattening. We have studied the kinetics of this process by depositing films onto precision-machined 2D sinusoidal surfaces and exposing these surfaces to solvent vapors. During solvent vapor exposure, the surface topology was continuously monitored using light interference microscopy. Results show that the sinusoid amplitudes decay exponentially with solvent exposure time, and the rate of decay is related to the surface frequency. Currently we are conducting experiments to determine how smoothing kinetics are related to polymer composition and molecular weight. Our recent experiments have been aimed at understanding the formation of undesirable low-mode roughness during smoothing of poly(amic acid) shells.

This work was performed under the auspices of the U.S. Department of Energy by the University of California Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

Advanced Target Designs for the Direct-Drive Inertial Confinement Fusion

V. N. Goncharov, P. W. McKenty, D. D. Meyerhofer, S. Skupsky, T. J. B. Collins,
P. B. Radha, T. C. Sangster

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LLE's base-line direct-drive ignition design for the NIF is an "all-DT" design with a 1-D gain of ~ 45 . Recent calculations show that targets composed of foam shells, wicked with DT, can potentially achieve 1-D gains ~ 100 . Current target design research includes exploring the use of adiabat shaping and the possibilities of performing direct-drive ignition experiments in NIF's x-ray drive configuration [Polar Direct Drive (PDD)].

This talk will review new advanced target designs and their relationship to current research.

This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC03-92SF19460, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

The Path to Develop Laser Fusion Energy

John D. Sethian and Stephen P. Obenschain
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Inertial Fusion with lasers, direct drive targets, and solid wall chambers is an attractive approach to fusion energy: A laser fusion power plant would be highly modular, which lowers risks and development costs and facilitates economical upgrades. The solid wall/direct drive approach is inherently simple. And encouraging technical advances have been made in the required science and technology. This talk will present the progress, challenges, and path forward to develop laser fusion energy.

The science and technologies for Laser Fusion Energy are being developed in concert with one another. The main components are being developed through the High Average Power laser (HAPL) program. This includes two lasers (Electra krypton-fluoride (KrF) laser at NRL and Mercury diode-pumped solid-state laser at LLNL), the chamber, final optics, target fabrication and target injection. Target designs and supporting experiments are carried out largely through the DOE as part of the stockpile stewardship program.

Recent advances include: Simulations indicate a suite of target designs with the potential to meet the energy requirements for gain, stability, cost, and injection into the chamber. Both lasers have demonstrated repetitive “first light”. A chamber “operating window” has been established that avoids first wall vaporization, allows target injection, and operates at reasonable efficiency. A model has been developed to study how the chamber conditions evolve between shots. Long term material behavior is being addressed with experiments that expose candidate first wall materials to fusion relevant ions and x-rays. Final optics experiments have shown that a grazing incidence aluminum mirror is highly reflective and exceeds the required laser damage threshold. For the targets; IFE sized divinyl benzene foam shells have been produced on a batch production basis; A method was developed to apply Au-Pd alloy coatings that can meet the requirements for the target physics, DT permeation times, and high IR reflectivity; and DT ice grown over a foam underlay has been shown to produce an ultra smooth layer, even at low temperatures. The cost of producing and injecting these targets has been modeled to be about \$0.16 each. A facility to accelerate, inject and track targets is undergoing first tests.

We propose to develop fusion energy in three distinct phases. The present Phase I program is developing the critical science and technologies. Phase II would develop, test and integrate full size components. Phase III is the Engineering Test Facility (ETF), which would be used to 1) optimize laser-target and target-chamber interactions, 2) develop of materials and components; and 3) demonstrate substantial net electricity generation at a high duty factor from fusion.. We could be prepared technically to start construction of the ETF within ten to twelve years

Researchers from 24 institutions have contributed to this program

This work is sponsored by the US Department of Energy

Production of Divinylbenzene Shells for the HAPL Program*

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Capsule designs for a Krypton-Fluoride laser based IFE reactor specify a 1700 μm layer of solid deuterium-tritium fuel contained within a 300 μm layer of 30–140 mg/cm^3 foam composed of only carbon and hydrogen with a 1–3 μm cell size. A 1–5 μm thick full density polymer overcoat will be applied over the foam followed by a 0.03 μm thick metal overcoat. Out-of-round and nonconcentricity are specified at 1% of radius and 1% of wall thickness respectively.

To meet these designs, divinylbenzene foam shells overcoated with a poly(vinyl phenol) layer are being developed. Foam shells have been microencapsulated at 50 and 100 mg/cm^3 with a 4 mm diameter and a 300 μm wall thickness using a triple orifice droplet generator. Out-of-round initially appears to be close to specification, but shell nonconcentricity has been a significant problem. Production factors such as density matching, interfacial tension, and agitation can affect physical shell dimensions and will be discussed. Shells have been overcoated, demonstrating the compatibility of the overcoating chemistry with the DVB foam, and developments in overcoating techniques will be presented. Optical characterization techniques will also be presented.

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Fabrication of a Double Shell Target With a PVA Inner Layer^{*}

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LLNL and General Atomics recently collaborated to build a set of ~1 mm double-shell targets that contained Xenon in the CH outer shell and ~10 atm of deuterium in the ~200 μ m silver-coated glass inner shell. To hold the Xenon in the outer shell, but not in the shell wall, a PVA permeation barrier was applied to the inside surface of the outer shell.

This presentation will describe the fabrication of this target including: (1) how the PVA layer was placed on the inside wall of 1 mm CH capsules using drop tower technology, micromachining and assorted processing techniques, and (2) how LLNL silver-coated glass shells and prepared mounting components. In addition, we will describe how the inner glass shell was inserted into the outer shell through a micromachined port and how the completed target was characterized.

^{*}This work was supported by the U.S. Department of Energy under Contract DE-AC03-01SF22266.

Tuesday

Poster Session

FORMATION OF A THERMOSTABLE GLASSY FUEL LAYER USING THE MINOR DOPE TECHNIQUE

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Formation of fuel layer (or cryogenic layer) with a smooth surface is one of the fundamental tasks in fabrication of the targets for inertial confinement fusion (ICF) and inertial fusion energy (IFE) programs. One of the promising technological trends is creation of the solid fuel layer with the glassy (liquid-like) structure. Such a structure of the fuel has an important advantage (as compared to any other modification of the solid isotope of hydrogen) from the point of view of applicability in fusion targets, i.e. extremely smooth free surface.

Earlier we have proposed and demonstrated a mechanism of formation of a smooth thermostable glassy solid layer of hydrogen inside a microshell based on introduction of minor dopes into the fuel (so called minor dopes technique or MD-technique) [1-4].

This report offers a more detailed overview and optimization of the method. The object under consideration is a microshell of ~1 mm dia filled with gaseous hydrogen H₂ and a minor dope of HD; density of H₂ is less than its critical density (30 kg/m³).

It is found that for glassy structure formation it is necessary to maintain uniform dope distribution in the hydrogen volume during the layering process. The calculations have shown that this is achieved by (a) implementation of the drop condensation mode within the time period of $t < 0.1-0.2$ sec, and (b) solidification of the liquid phase within the time period of $t < 10$ sec. The results of calculations are confirmed by relevant experimental research work.

Current results in the area of (a) specific features of formation of the glassy layer of D₂-fuel with minor dopes, and (b) potentials for use of the MD-technique for larger fuel quantities (IFE target) are discussed.

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Parametric Study of Infrared Layering*

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Cryogenic targets for the National Ignition Facility require uniform solid hydrogen layers inside spherical capsules with a design point central gas density of ~ 0.3 mg/cc. This gas density corresponds to an ice temperature that is 1.5K below the triple point of hydrogen. Previous experiments have shown that pumping the IR collisionally induced vibration-rotation band of solid hydrogen contained inside a transparent plastic shell generates a volumetric heat source in the hydrogen lattice and significantly helps the formation of a spherical ice layer inside the plastic shell. To determine if it was possible to reach the design point temperature using IR, a series of proof-of-principle experiments investigated slowly cooling down uniform, solid deuterium hydride (HD) layers under high IR volumetric heating rate. Using a cooling rate of ~ 3 mK/min and an equivalent β -layering volumetric IR heating rate of ~ 25 QDT (1QDT=50mW/cc), ice layer quality was maintained to an equivalent design point temperature of 1.5K below the triple point of HD. This large volumetric heating rate generated by the IR may produce unmanageable temperature drops inside an ignition hohlraum. Based on these results, we have begun a parametric study to determine values for optimal IR volumetric heating rate versus cooling rate. We report here on the results of these studies.

* Work supported by U.S. Department of Energy under Contracts DE-AC03-01SF22260 and W-7405-ENG-48.

Refractive index measurement of solid hydrogen*

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Abstract

Precise optical characterization of hydrogen fuel layers in NIF scale hohlraums requires the refractive index be known to less than 1 part in 1000. We employ angular resolved spectral interferometry to measure the refractive index without the need to know precisely the ice thickness. We will show the initial results of these measurements on hydrogen and deuterium and discuss the extension to deuterium-tritium.

* This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

Accuracy limits of fuel layer characterization in an indirect drive cryogenic hohlraum

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We describe initial results of a study to determine the accuracy limits of ice layer characterization in an indirect drive hohlraum target using shadowgraphy and spectral interferometry diagnostic techniques. These techniques have been demonstrated to give highly accurate measurements of the ice layer characteristics in a fuel shell over a long range of scalelengths. However, the limited hohlraum optical access (via the laser entrance holes) restricts the achievable accuracy of modal characterization of the ice layer. We discuss theoretical limits to accurately defining the ice layer as well as experimental limits due to uncertainties in the measurements. We will also discuss ideas for reducing some of these limitations.

This work was performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

Design for Fiber Injection of IR into a Hohlraum*

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Cryogenic targets for NIF require uniform solid hydrogen layers inside spherical capsules. Experiments have shown that pumping the IR collisionally induced vibration-rotation band of solid hydrogen contained inside a transparent plastic shell generates a volumetric heat source in the hydrogen lattice and aids in the formation of a smooth spherical ice layer inside the plastic shell. Recent experiments have investigated optical IR injection techniques for creating smooth ice layers inside 2 mm capsules (with attached fill tubes) suspended in NIF scale hohlraums. In these experiments a beam of IR light was injected into the hohlraum through each laser entrance hole where it scattered off of roughened hohlraum walls to illuminate the capsule and ice layer. Adjustable external reflective optics provided control of the layer shape. In an effort to develop a more compact IR injection scheme we have designed a hohlraum that fiber couples the IR directly into the hohlraum. Modeling studies have shown that three equally spaced fibers attached to each end of the hohlraum provide suitable capsule illumination. We present the design of the experimental six fiber injection hardware currently being constructed for an upcoming series of fiber injection experiments.

* Work supported by U.S. Department of Energy under Contracts DE-AC03-01SF22260 and W-7405-ENG-48.

IR ABSORPTIVE PROPERTIES OF PLASTIC MATERIALS USED IN ICF CAPSULES

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One approach to improving the quality of the DT ice layer on the inside of a NIF capsule target is to enhance the natural β -layering process by heating the ice with infrared light (IR) tuned to a D_2 or DT excitation band. However to do this the IR must pass through the capsule wall, and absorption by the capsule material results in heat generation that is deleterious both in terms of reducing the energy input to the ice as well as increasing the difficulty of symmetrically cooling the capsule. In order to optimize the choice of wavelength we have measured the wavelength dependent transmission properties of IR through the plastic materials we are considering for capsule fabrication. We will present wavelength dependent extinction coefficient data for normal and fully deuterated plasma polymer, both Ge-doped and undoped, and vapor deposited polyimide.

This work was performed under the auspices of the U.S. Department of Energy by the University of California Lawrence Livermore National Laboratory under contract W-7405-Eng-48 and by General Atomics under contract DE-AC03-95SF20732.

Mechanical and Permeation Properties of Thin GDP Shells Used as Cryogenic Direct Drive Targets at OMEGA^{*}

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Thin glow discharge polymer (GDP) shells are currently used as the targets for cryogenic direct drive laser fusion experiments. These shells need to be filled with nearly 1000 atmosphere of D_2 and cooled to cryogenic temperatures without failing due to buckling and bursting pressures they experience in this process. Therefore, the mechanical and permeation properties of these shells are of utmost importance in successful and more rapid filling with D_2 . In this paper, we present an overview of buckle and burst pressures of several different types of GDP shells. These include those made using traditional GDP deposition parameters (“normal GDP”) and using modified parameters (“strong GDP”) leading to more robust shells. We also present data on deuterium permeation time constants of thin shells using a mass spectrometer.

^{*}This work was supported by the U.S. Department of Energy under Contract DE-AC03-01SF22266.

Plasma Diagnostic Study of the GDP Coating System Used for OMEGA Cryogenic Target Fabrication*

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Thin glow discharge polymer (GDP) shells are currently used as targets for direct drive cryogenic experiments at OMEGA. We have studied the GDP deposition system using several plasma diagnostics to obtain a correlation between plasma conditions and the strength of GDP shells. Optical emission spectroscopy was used to determine the presence of CH species in comparison to atomic and molecular hydrogen as a function of several coating parameters. Higher relative concentrations of atomic hydrogen correspond to stronger, smoother coatings. Electron density and temperature was also determined using Langmuir probe measurements. High electron density and temperature also leads to stronger coatings. Mass spectroscopic results are also discussed.

*This work was supported by the U.S. Department of Energy under Contract DE-AC03-01SF22266.

DETAILS OF THE COATING PROCESS AND MATERIALS PROPERTIES FOR VAPOR DEPOSITED POLYIMIDE

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We have continued to gain better understanding of both the deposition process and material properties of the vapor deposited polyimide. Refinements to the evaporator design have improved the reproducibility of monomer delivery. Experiments have shown that the tungsten filament used to prevent charge accumulation on the shell also produces radiant heat that preferentially drives off PMDA. We have adjusted the evaporated stoichiometric ratio to compensate for radiant heating of the shell. A new mix chamber attached to the evaporators produces a more uniform composition across the coating area. A new method for shell agitation (tilted pan) has resulted in improved coating surface smoothness, improved shell position control, and fewer shells sticking during coating. The combined effect of the mix chamber and tilted pan shaking has reduced shell coating rate and composition variations. We have found, prior to thermal curing, that the polyamic acid coating is susceptible to hydrolysis. Hydrolysis of the surface produces low mode roughness during the solvent vapor smoothing and curing process. Minimizing air exposure prior to solvent vapor smoothing has resulted in a higher yield of shells meeting NIF specifications.

This work was performed under the auspices of the U.S. Department of Energy by the University of California Lawrence Livermore National Laboratory under contract W-7405-Eng-48.

Implementation and Effects of Closed-Loop Controls on OPO IR Sources for Cryogenic Target Layering

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Creating high-quality ice layers in cryogenic targets requires a stable IR source that is invariant to environmental changes. Experience and testing have shown that the optical parametric oscillators (OPO's) currently in use are affected by fluctuations in room temperature and have insufficient stability for reliably layering cryogenic targets. It has also been found that varying the stresses in the multimode fiber used to carry IR light to the layering sphere changes the power delivered. Since it is desirable to form the ice layer as close to the triple point as possible, a drifting light source can melt the target's ice layer. We have modified one of the cryogenic layering spheres and added an InSb detector to monitor the OPO power in the sphere. Through the use of a closed-loop control, we have shown IR laser stability to $\pm 0.2\%$ over a 24-h period. The software and hardware issues involved in implementing this loop are presented. The effects of higher stability on ice-layer quality and layer times will also be presented.

This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC03-92SF19460, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

Fabrication of Laser Targets Requiring Novel Depositions

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Abstract

Luxel is best known in the target fabrication community for supplying gasbags and polyimide windows. However in addition to these products, we also have a great deal of experience in the fabrication of thin film targets. This poster will present examples of novel targets that Luxel has made in recent years by deposition, and the challenges and techniques that were developed to allow successful fabrication.

Some of these novel thin film targets include:

Quad-Mix Target – This target consisted of a 5micron thick 25% mixture each of Eu, Sm, Gd, and Nd deposited on 20micron thick Lexan.

Multi-Layer Target – This target required a layer of 300Å C over 418Å Se which was deposited on 400Å polyimide film.

Backlighter Wedge Coating – Luxel recently coated backlighter wedges with a 50:50 mixture of Sm and Eu to a thickness of 1micron.

Micro-Dots – This target consisted of 50micron diameter dots of 4micron thick Al which were laminated in Lexan sheets. Other microdot target materials have included Mo:Ag, Au, and Au:KCl on customer supplied Be film.

Other examples of custom fabricated products requested by target physicists include photocathodes (Au or CsI, KBr, and KI salts w/Al overcoat) and accelerator grids (750 line per inch Ni mesh).

Luxel uses a variety of production methods to deposit these materials including evaporation, e-beam, and sputtering. The resulting thin films can be used free-standing in a frame, however they often require additional support to withstand pressure differentials and/or handling. We have experience supporting thin film targets using polyimide, Lexan, and stainless steel or nickel mesh.

Prefer poster presentation

Fabrication of Foam and Film Targets for ICF *

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Flat foam targets for inertial confinement fusion were made from resorcinol-formaldehyde (RF) polymer material using appropriate molds. The foam targets were of varying densities and thickness with and without patterns depending on the experimental requirements. Of particular interest is the fabrication of high density (250 mg/cc) RF foam target with sine wave pattern micro machined on the foam. Preparation of combination targets comprising of plastic film and foam was also explored by casting the foam on film. Attempts to make foam-film targets with sine wave pattern machined on the plastic film will be discussed. These targets were intended for Richtmeyer-Meshkov and feedout studies.

Flat plastic (CH) film targets were also made incorporating specified atomic percent of dopants such as silicon and chlorine for diagnostic purposes. The films were made by evaporation of solutions of appropriate concentrations of the doped polymer. Assembling and characterization of the targets will be presented.

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Development and Fabrication of Targets for Materials Studies at the Los Alamos Trident Laser

R. A. Perea, E. V. Armijo, R. D. Day, J. M. Edwards, F. P. Garcia, R. Manzanares, A. Nobile, D. Paisley, R. J. Sebring, D. L. Sandoval and R. C. Snow

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Experiments are being conducted at the Los Alamos Trident laser to study shock propagation and spall properties of materials. These experiments are for the purpose of making the necessary preparations to perform experimental campaigns to study the material spall properties of Pu. The experiments involve laser-launched flyer plates where a high velocity flyer plate impacts a target material sample. An optically-based diagnostic measures the response of the target material sample as it is impacted by the flyer plate. Components have been developed and fabricated for flyer plate assemblies as well as the target material samples. Fabrication of the flyer plate assemblies begins with a BK-7 glass substrate onto which is deposited 0.5 μm C, 0.5 μm Al and 0.5 μm Al_2O_3 . Onto these deposited layers is glued a 250 μm Au or Cu plasma shield. Onto the plasma shield is glued a flyer plate disk (5-8 mm diam.) with thicknesses in the range 500 to 1200 μm . Flyer plates are diamond turned Au or Cu. Fixturing and tooling needed to glue these components together so that they are very flat have been developed and demonstrated. A metrology method for the flyer plates was used that involves simultaneous measurement of the upper and lower surface of the flyer plate using confocal lasers. This measurement provides the flyer plate thickness as well as the upper and lower surface profile. Such a measurement is necessary in order to confirm that the flyer plate meets the required specifications of uniform thickness and overall flatness. After the flyer plate is glued down, WYKO measurements are made of the overall flyer plate assembly thickness profile. The target material samples were cylindrical samples that consisted of an inner cylinder that is press fit into an outer cylinder. These components were successfully used in experiments to demonstrate the measurement of material spall on non-radioactive components (Au and Cu). Experiments planned for the near future will use these components to study the material spall properties of Pu. This poster discusses the development, fabrication and characterization of the flyer plate assemblies and target material samples.

Preferred Presentation Format – **Poster**

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New ICF Target Development*

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The GA/Schafer team has produced targets for Inertial Confinement Fusion (ICF) and High Energy Density Physics (HEDP) programs for over ten years. During that time we have seen requirements for targets change significantly, nearly always toward more complexity, new materials, and increased requirements for precision. Sometimes, completely new materials or assembly techniques are required for new types of targets. Additionally, characterization requirements have increased as diagnostic capabilities have improved. When new materials and target geometries are developed, they often require new characterization capabilities rather than improvements in existing capabilities.

This poster will describe GA/Schafer experience with respect to the time required to develop new HEDP and ICF targets. Factors that affect development time are complexity of the targets, assembly requirements, material development, and characterization. We examine each factor for various types of targets, in each case considering the entire development cycle from pre-order discussions between experimenters and target fabricators to target delivery.

The targets that we will examine include SNL Capsule Implosion Targets, NRL EOS Targets, NRL Patterned Foam, LLE Doped Foil, and LLE Shells. These targets each involved one or more of the factors enumerated above and are useful to demonstrate the way these factors affect development time.

Because the time between an experimenter's request and the fabricator's delivery can be over a year in extreme cases, it is very important that the target fabricator becomes involved as early as possible in the experiment design process. We will also present ways that the experimenter/modeler/target fabricator team can reduce the time required bring a target from idea to hardware.

*This work was supported by the U.S. Department of Energy under Contract DE-AC03-01SF22266.

Rapid Adaptability in Production Techniques for Complex Vulcan Experiment Targets

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CCLRC Rutherford Appleton Laboratory, UK

Fabrication techniques for two complex target types produced in the Target Preparation Laboratory at RAL during the past year are presented. Specifically details will be given for 1) Advanced Fast Ignition Targets with particular emphasis on micromachining and plating used in cone production and 2) Helmholtz coil targets (used in the production of intense magnetic fields) with particular emphasis on the use of high precision jigs for microdeformation and microassembly. The deliverable quality using different production techniques was measured and the procedures which routinely gave the highest quality for minimum assembly time were adopted and are described here. In summary, whilst being rapidly responsive to changes in target design occurring during the course of experiments, targets were made with enhanced reproducibility and minimized production time.

Investigating Machining Variables on Various Substrates*

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Schafer's diamond turning machine is often used to manufacture parts for targets. The substrates used vary, as do the parameters for machining. Research has been done to determine what machining techniques provide the best finished products on a variety of substrates with a variety of finished products desired. This paper will look at the techniques used at Schafer to machine RF, polystyrene, and aluminum in order to make step targets and sine waves with low RMS finishes.

*This work was supported by the U.S. Department of Energy under Contract DE-AC03-01SF22266.

OPTIMIZATION OF HIPE FOAMS

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High Internal Phase Emulsion (HIPE) polystyrene foams have been made at LANL for the past decade. It is a robust system that offers flexibility in tailoring density and the incorporation of halogens and metals. As target designs become more complex the demands placed on the foams are more stringent. Parts are machined from 30 mg/cm³ foams to thicknesses of 50 µm. At three percent of full density these foams are to withstand extraction with ethanol to remove the wax utilized as a machining aid and not allow shrinkage or warpage. In order to accomplish this the formulation of the HIPE foam had to be modified.

Recently some new processing issues have arisen. At low densities voids have become a problem. To determine a formulation that reduces void content and allows minimum shrinkage, experimental design was utilized. We also developed an image analysis techniques that allows us to quantify the amount of voids in the system. These techniques also allow us to evaluate the surface finish of the foam. In order to machine these low density foams to the tolerance required with an optimum surface finish the foams are backfilled with Brij 78, an alcohol soluble wax. After the part is machined, the Brij is leached out. Recent batches of Brij have exhibited high shrinkage, which in turn affects the surface finish of the foam.

Experimental design, troubleshooting and image analysis will be presented.

Fast Ignition Target Requirements*

R.B. Stephens, S.P. Hatchett, C. Stoeckl, K.A. Tanaka, and H. Shiraga

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The current concept for a direct drive fast ignition target uses a reentrant cone to isolate one sector over the compressed shell from its own blowoff. The cone substantially complicates the implosion dynamics compared to a spherical target. We are examining the collapse of such structures in experiments at Omega. The implosions have been characterized with x-ray framing cameras, in both backlit and emission configuration, and the results compared to a Lasnex model. The images show good collapse symmetry, but surprisingly strong heating of the tip of the gold cone. The consequences of these observations for design of a cryo-ignition target will be discussed.

*This work was supported by the U.S. Department of Energy under Contract DE-AC03-01SF22266.

Wednesday Oral Session

Shell-Target Formation and Installation to Produce Microspheres from Metastable Materials.

N.G. Borisenko, N.A. Chirin*, V.M. Dorogotovtsev, V.V. Gorlevsky*, Yu.E. Markushkin*, Yu.A. Merkul'ev, P.A. Storozhenko**, R.A. Svitsin**.

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The foaming method developed for spherical shells to be made from metastable substances such as BeD₂ or amine-boran is discussed. For laser target production these works have started a few years ago [1,2]. The installation for such shell production has been designed and then manufactured basing on the preliminary material study. It is a vertical vacuum furnace in which the initial granules are foamed in a free fall. The installation tests and the obtained shell characteristics are presented.

The first laser experiments with beryllium deuteride foams are reported.

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(poster or oral)

An overview of beryllium capsule fabrication activities at Los Alamos National Laboratory

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R. D. Field^a, R. E. Hackenberg^a, J. M. Herrera^a, A. Nobile^b,
P. A. Papin^a, G. Rivera^b, R. K. Schulze^a and D. J. Thoma^a

^a*MST-6: Materials Technology-Metallurgy*

^b*MST-7: Materials Technology-Polymers/Coating*
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Beryllium-copper, Be0.9at.%Cu, capsules have been identified as one of the leading target choices for the National Ignition Facility. Production of these nominally 2 mm diameter spheres with 150 micron walls requires a unique combination of capabilities and processes. The route by which bulk beryllium is transformed into a beryllium-copper capsule requires melting, alloying, casting, extrusion, machining, bonding, and polishing. Workers at LANL can currently perform each of these steps independently but not yet so well that all NIF specifications are met. Work is proceeding to both integrate these steps into the unified process described here and to meet the specifications required for NIF capsules.

The process begins by melting Be in a high purity argon atmosphere to remove volatile impurities and transport oxides to the surface. The oxides are then removed by etching. The process is repeated four times. Copper is added at a level of 0.9at.% by melting the Be and Cu together 6-10 times. The resultant material has grain sizes ranging from 50 to 500 microns, far too large for NIF capsules. A process called equal channel angular extrusion, ECAE, will be used to reduce the grain size. The cast grain size is first reduced by casting into a 5 mm diameter rod in a large copper mold where it cools more quickly. The resultant grains are long, 500 microns or more, but uniformly narrow, less than 50 microns. The rod is encapsulated in a Ni can to prevent Be contamination of the work area and personnel during the extrusion process. The encapsulated rod is extruded through a fixed angle, often 120 degrees, at elevated temperature. ECAE produces a strain of approximately 0.6 for each 120 degree pass and has been demonstrated to reduce grain size in pure Be made from powders, but not yet on cast alloys. The expected maximum grain size is less than 20 microns. Capsules are to be made from the extruded material by machining half hemispheres into cylindrical specimens, which are then bonded together to form a rod with a spherical cavity. A sphere concentric with the cavity is then machined from the rod and polished. The bonding process consists of sputter cleaning and sputter deposition of aluminum on the bond surfaces to prevent the formation of BeO at the bond line. The two cylindrical specimens are clamped together and heated to melt the aluminum and form a solid strong bond. Bonding has been demonstrated, but not yet with sufficient strength. Final machining and polishing complete the process.

Abstract for 15th Target Fabrication Specialists Meeting, Gleneden Beach, Oregon,
June 1-5, 2003

Grain Refinement in Beryllium by Equal Channel Angular Extrusion

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Ultrafine-grained Be is the material of choice for fabrication of the NIF target capsules. One method of producing ultrafine grains in metals is by imposing very large strains. Equal channel angular extrusion (ECAE) has been used to achieve these high strains. Previous work has shown that powder-source Be can be successfully processed by ECAE. Pure Be and Be-0.9 at% Cu alloys have been arc melted and cast into billets 5 mm in diameter by 30 mm in length. These billets were enclosed in cans fabricated from commercial purity Ni, with an electron-beam welded end plug. These cans were extruded at 425°C in ECAE tooling with a 120° angle between the inlet and outlet channels. The billets were extruded up to 4 times. The microstructures of the powder-source Be and the arc-melted Be and Be-0.9 at% Cu materials will be presented, and the effects of the ECAE processing on the grain size will be discussed.

Microstructural Characterization of Be Capsule Bonds

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Abstract

The machining and bonding of hemispherical Be capsule shells is a promising approach to produce targets for the ICF program. As these bonds may limit the mechanical strength of the capsules, the effects of processing (during bond formation) on the microstructure are highly relevant. This study reports on the processing and microstructural characterization of Be-Al-Be brazes produced as follows: the bonding surfaces of the two Be halves were sputter cleaned with Ar⁺ prior to being sputter coated with a 0.7 micron thick layer of pure aluminum. The two halves were then brazed together at 750C for either 1, 10 and 100 minutes under vacuum in a RF heated dilatometer. Transmission electron microscopy of the resulting bond region revealed that it was free of voids. AlN precipitates were found in the central Al region; they were nanometer-sized at 1 minute at 750C though their size substantially increased with longer holding times. Some strain-hardening of the adjacent Be regions was also observed. The origins of these microstructural features will be discussed, as will their implications for the capsule bond strength.

Abstract to be submitted to
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June 1-5, 2003
Glenden Beach, Oregon
-oral presentation preferred-

Sputter-deposited Be for NIF capsule ablators*

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Sputter deposition remains a promising approach for the manufacture of Be-based NIF capsule ablators. Among its advantages are the ability to change dopant species and concentrations with relatively modest effort. It also makes feasible designs with graded dopant profiles. Concomitant ion bombardment is used to reduce grain size and increase coating density. We have discovered that the coating density decreases as the diameter of the capsule increases, a surprising finding that is currently under study. Because these coatings are essentially impermeable, we are developing a drill and plug technique to fill the capsules with the required fuel (typically several hundred atmospheres of DT). We have successfully used a femtosecond pulsed laser to drill sub-5- μm diameter holes in 125- μm -thick Be layers. Initial experiments in which Be foils were exposed to sub-millisecond IR laser pulses at various powers have demonstrated results ranging from no effect to hole drilling, with a clear melt zone at intermediate levels

*Work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract W-7405-ENG-48.

Infrared formed and controlled fuel layers inside of hohlraums*

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Abstract

Infrared smoothed deuterium (D_2) fuel layers inside of a spherical capsule have been successfully demonstrated inside of NIF scale cylindrical hohlraums. Infrared (IR) laser light injected through both laser entrance holes is scattered by the roughened gold hohlraum wall, illuminating a 2 mm diameter, 40 μm thick shell with 100-200 μm thick D_2 ice. Control of the low modes is shown by moving the IR both perpendicular and parallel to the hohlraum axis. These results show the IR power balance must be equal to within 0.6% and the IR pointing along the hohlraum wall must be controlled to within 300 μm to meet the axial P_1 and P_2 NIF specifications. Alternative illumination geometries using fiber optics, IR power limitations, and characterization methods will also be discussed.

* This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

Effects of Cooling and Hydrogen-Ice Formation on the Out-of-Roundness of Cryogenic Fuel Capsules

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Abstract

Capsules used in current cryogenic target experiments on OMEGA are $\sim 900\ \mu\text{m}$ diameter with a wall thickness as thin as $3\ \mu\text{m}$ ($1\text{-}\mu\text{m}$ -thick capsules are planned for future experiments). Stress introduced into these thin-walled polymer capsules during the fabrication process can cause distortion from spherical symmetry during cooldown of the capsule to solid hydrogen temperatures. In addition, the solidification of the hydrogen can impart additional deformation in the capsule's wall. The magnitude of these effects was investigated by imaging the capsule during cooldown with a 1024×1024 -pixel charge-coupled device (CCD). Image-processing routines were subsequently used to locate the perimeter of the capsule within 0.1-pixel accuracy. By rotating the capsule and acquiring multiple views, the overall sphericity of the capsule was measured. Sphericity data as a function of temperature and hydrogen phase (liquid and solid) are presented.

This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC03-92SF19460, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

Experimental studies of natural convection driven asymmetries in cryogenic hydrogen layers

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We describe experiments and simulations that investigate the effects of steady-state natural gas convection on hydrogen ice layers formed on the inner surface of a 2 mm diameter transparent spherical shell. These experiments are part of an ongoing effort to benchmark models used to calculate the natural convection expected to be present in a cryogenic NIF-scale ignition hohlraum. The experiments are done by suspending the shell in the center of a cryogenically cooled 1-inch diameter integrating sphere using a fill-tube extending from the top of the shell to the top of the sphere. Low pressure Helium exchange gas fills the volume surrounding the shell. Small windows provide optical access to the ice layer. Heat generation from the ice and capsule via IR power absorption creates steady-state toroidal convection cells in the helium gas surrounding the shell. The convection cools the bottom of the shell more than the top causing the equilibrium shape of the ice to be thicker at the bottom. The data consists of measuring the ice layer position in a shadowgram as a function of helium gas pressure. We simulate the experiment using a finite element model that solves the fluid and heat equations. The calculations determine the helium gas pressure that is most consistent with prescribed distortions of the ice layer. We will show the experimental results, compare with the simulations, and discuss the convection experiments planned for the NIF scale hohlraum target.

This work was performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

Thermal and hydrodynamic study of cryogenic target for the LMJ.

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The cryogenic target temperature inside the hohlraum has been studied with a computational fluid dynamics code (FLUENT).

Two-dimensional (2-D) and three-dimensional (3-D) models were developed and used for the thermal and hydrodynamic calculations.

First, with thermal calculations only, we have found the optimum heat flux required to counteract the effect of the laser entrance windows. This heat flux is centered around the hohlraum wall along the revolution axis. The temperature surface profiles of the capsule and the DT ice layer were significantly reduced (enough to reach the LMJ specifications (i.e. $\Delta T < 1\mu\text{m}$)). Then, the sensitivity of the target temperature profiles (capsule and DT layer) against misalignment of the capsule from the center of the hohlraum along the radial and the longitudinal axis was investigated. The maximum offset acceptable was determined.

Besides, the effect of the shield extraction (shield surrounded the cryogenic structure) was studied and has indicated that the maximum target lifetime before the laser shot was less than 1s.

Meanwhile, with hydrodynamic studies, we have investigated the surface temperatures profiles alteration due to hohlraum filling with a equal mixture of He and H₂.

The accuracy of the results is given with five significant digit outputs. As the properties of the materials are not given with an adequate accuracy and the number of cells in the mesh has to be restricted, results were more qualitative than quantitative.

Indirect drive LMJ target fabrication specifications

*S. Laffite, M. Bonnefille, F. Chaland, C. Cherfils, D. Galmiche, J. Giorla, P. A. Holstein and
Y. Saillard*

The "LMJ" (Laser MegaJoule) laser is planned to be built in France, by 2010. Between 1 and 2 MJ of laser energy will be delivered, which will permit to achieve ignition. The indirect drive ignition target fabrication has to be specified. We have begun the theoretical part of this study. After recalling the LMJ target design, we present here the first results of our calculations. It includes specifications of the DT gas density, the H-HE gas density and the polyimide window parameters, and the study of the hydrodynamic stability of the capsule.

Inertial fusion cryogenic activities at the CEA Low Temperatures Laboratory

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The goal of the CEA low temperatures laboratory (SBT) is to find and to develop solutions for cryotechnological problems, which appear with large fundamental research facilities, like accelerators (LHC) or tokamaks (ITER). For this reason the SBT is responsible of different cryostats dedicated for LMJ experiments. The main results obtained today concern the filling target process, the thermal regulation, and a full scale cryotarget positioner system.

A prototype of cryocompressor has been tested at the SBT with a range from 0 to 1500 bars. The principle is to condense gas into a cell with a finite volume at 15K and after to warm up this one until 300K. The complete cool-down from 300K to 10K may be lowered to 3 hours. To achieve the maximal pressure, the condensing cell may be warmed up to 300K by means of a 600W heater. This heater may be controlled either by temperature (10K-40K) or by pressure (40K-300K). The total duration of pressure ramping is in the range of 3-4 hours to 48 hours. The increase of pressure versus time may be linear or have another shape. A computer program can drive this slope between 0.25bar/min to 6 bar/min. The prototype has been successfully tested with Hydrogen and Deuterium until 1500 bar.

The cryogenic target requires a cooling down with strong constraints. A thermal regulation based on a very stable single gas phase flow has been studied on a dedicated cryostat. This regulation uses a homodyne detection to enlarge the signal-to-noise ratio. A computer model based on the Laplace transform, predicts the behaviour of this system to respond in the range of 0.001 Hz to 0.1 Hz. Now the results show that a regulation with a margin of +/- 0.2 mK can be reached. Cooling down experiments has been done with a slope of 1mK/min and a deviation less than +/-0.3 mK. This model allows determining the regulations parameters adjustment.

For testing a lot of components and to prepare the design of the real cryostat, a mock-up of the cryotarget carrier called "Echelle 1" has been done. With this cryostat, lot of experiment can be planned. This cryostat ran into service at the beginning of 2002. The essential measurements are the thermal losses of the liquid helium reservoir and the autonomy. With a flow of 2.7 LHe per hour, the target can be cooled until a temperature of 14 K. The low heat losses of the flexible cryoline (180mW/m) limit the consumption to 3LHe per hour. The next step is the installation of the hexapod to displace the target and to analyse the behaviour of the system to follow the set point when the target is in alignment process.

The CEA/LMJ program supports this work.

Experiments on filling and layering capsules in hohlraums

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We describe experiments that have taken place in the newly operational Deuterium Test System (D2TS) at LLNL. The D2TS provides the capability to perform integrated tests with many of the technologies necessary to deliver and shoot a cryogenic target. Specifically, with this apparatus LLNL has the capability to carry out cryogenic layering studies on a permeation filled plastic capsule mounted in a hohlraum. Procedures used to successfully fill and cool NIF ignition scale targets to cryogenic temperatures will be reviewed. Recent experiments on making D₂ layers in these targets will also be discussed. These experiments are the first without fill tubes at LLNL. Techniques being used to create symmetrical layers include slow cooling, infrared layering, and thermal shimming.

This work was performed under the auspices of the U.S. Department of Energy by the University of California Lawrence Livermore National Laboratory under contract W-7405-Eng-48.

Wednesday Poster Session

Development of Copper Doped GDP Coatings*

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Copper doped polymer shells can provide a very useful diagnostic for fast ignition experiments currently being performed at various laboratories around the world. The low concentration copper dopant acts as an efficient x-ray source providing information on the physics of fast ignition. We have developed copper doped glow discharge (GDP) coatings suitable for such purposes. Copper acetylacetonate (CuAcAC), a solid at room temperature, was used in a heated jacket as the dopant source. We used this technique to fabricate thin ($\sim 5\text{--}7\text{ }\mu\text{m}$) GDP shells doped with ~ 1 at % copper through the depolymerizable mandrel process for fast ignition experiments. The details of the experimental set up and the range and limitations of the technique are discussed.

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Fabrication of Gas Filled Tungsten-Coated Glass Shells for HED Experiments*

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Deuterium filled, glass shells, $\sim 850\text{ }\mu\text{m}$ in diameter and $\sim 3\text{ }\mu\text{m}$ in thickness, overcoated with $\sim 3\text{ }\mu\text{m}$ of tungsten are desired for High Energy Density (HED) experiments. In this paper, we report on fabrication of such shells. Tungsten was deposited on glass shells placed in a specially designed holder and agitated using an intermittent tapping technique. Coating thickness was measured by weighing the shells and destructively by interferometry on shards. The uniformity was found to be $<10\%$ as measured destructively by interferometry and electron microscopy, and non-destructively by rolling shells down a smooth incline. The surface finish of tungsten coatings on shells depended on the source to substrate distance which also determined the coating rate. Atomic force microscopy measurements of the surface finish of coated shells are presented. When the glass shells were filled prior to the coating, it was found that most of the gas escaped from the shells during the coating process due to high temperatures experienced. However, we found that, perhaps due to the columnar structure of the coatings, the overcoated shells could be filled with deuterium at elevated temperatures.

*This work was supported by the U.S. Department of Energy under Contract DE-AC03-01SF22266.

Permeation Barrier Development for Multi-millimeter CH Capsules Used on the Z-machine*

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Many of the two to five millimeter CH capsules needed for experiments on Sandia's Z-machine require a low-Z permeation barrier to hold hydrogen isotopes and diagnostic gases. The application of such a barrier is developmental and has never been done before. This barrier must have good thickness uniformity and must maintain a full gas load for a period of weeks due to the extensive time it takes to assemble, characterize and load targets on Z.

This presentation will describe our current methods of coating 2 mm CH capsules being used on Z with permeation barrier materials, i.e., PVA, aluminum and/or glass. These methods include PVA “spin-and-dab” coating and sputter coating of both aluminum and glass. In addition, this presentation will describe how we characterize coated shells for wall uniformity and gas retention characteristics

*This work was supported by the U.S. Department of Energy under Contract DE-AC03-01SF22266.

Microstructures of Ultralow-Density TPX Foam Obtained by Altering the Coagulant Alcohol

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The present report describes ultralow density ($2\text{--}12\text{ mg/cm}^3$) plastic (CH_2) foams whose density is close to the cutoff density of the plasma for visible and near-infrared light beams ($0.55\text{--}1.3\text{ }\mu\text{m}$). These foams are prepared from a poly(4-methyl-1-pentene) gel with alcohol derivatives by extraction using supercritical fluid CO_2 . Their microstructure ($2\text{--}10\text{ }\mu\text{m}$) was finer than that of the previous poly(4-methyl-1-pentene) foam and could be varied using different alcohols. For example, among the foams obtained from hexanol derivatives gel, the ordering of the density was 1-hexanol > 2-methyl-1-pentanol > 2-ethyl-1-butanol, where the linear 1-hexanol induced a higher density than the branched alcohol. This result agrees with the kinetic-controlled gelation mechanism, and indicates a guide to control microstructure of ultralow density foam.

FABRICATION OF UP TO 4-MM DIAMETER MICROENCAPSULATED P α MS MANDRELS FOR HIGH GAIN TARGET DESIGNS

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In recent years we have demonstrated that 2-mm-diameter P α MS mandrels meeting NIF surface symmetry specifications can be produced using microencapsulation methods, and that these mandrels can be successfully overcoated with plasma polymer and pyrolyzed to produce thermally stable GDP mandrels which maintain the symmetry of the original P α MS shell. Recently higher gain target designs have been introduced that rely on frequency doubled (green) laser energy and require capsules up to 4 mm in diameter, nominally meeting the same surface finish and symmetry requirements as the existing 2-mm-diameter capsule designs. In order to evaluate whether the current microencapsulation-based P α MS mandrel fabrication techniques will adequately scale to these larger capsules we have explored extending the techniques to 4-mm-diameter capsules. We find in our preliminary investigations that microencapsulated shells meeting NIF symmetry specifications can be produced, and in this poster will detail the processing changes necessary to accomplish this.

This work was performed under the auspices of the U.S. Department of Energy by the University of California Lawrence Livermore National Laboratory under contract W-7405-Eng-48 and by General Atomics under contract DE-AC03-95SF20732.

Beryllium Capsule Filling Equipment Design Studies *

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This paper presents the latest developments in the conceptual design of equipment for the DT filling and sealing of Beryllium capsules. Two approaches have been pursued in parallel.

In the first approach, a pre-drilled capsule is filled by cryocondensation of DT gas at low pressure, and then the fill hole at the top of the capsule is laser sealed through a port in the filling chamber. A conceptual layout of a cryocondensing and laser sealing assembly based on a commercial cryocooler is presented, together with an analysis of the precision of the DT pressure measurement required to obtain the desired amount of DT fill.

In the second approach, a stack of mated pairs of beryllium cylinders, each with a hemispherical cavity, is placed in a vessel. Next the vessel and the cavities are filled with high-pressure DT gas. The cylinder pairs are then pressed together by a weight, heated to high temperature, and diffusion bonded into sealed cylinders, each containing DT gas in a spherical cavity. A preliminary design of the filling and bonding cell is shown, including items that hold and press the beryllium cylinders together, thermal insulation, electrical heater, and instrumentation. The steady state and heat up thermal analyses of the bonding cell are also presented.

*This work was supported by the U.S. Department of Energy under Contract DE-AC03-01SF22266.

Fabrication and Characterization of Targets for Shock Propagation and Radiation Burnthrough Measurements on Beryllium-Copper Alloy

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Beryllium-copper alloy (Be0.9%Cu) ICF capsules are being developed for the pursuit of thermonuclear ignition on the National Ignition Facility (NIF). Success of this capsule material requires that its shock propagation and radiation burnthrough characteristics be understood to an accuracy of a few percent. To this end, experiments are being conducted to measure the shock propagation and radiation burnthrough properties of Be0.9%Cu alloy. These experiments involve measurements on small Be0.9%Cu wedge, step and flat samples. Samples are mounted on 1.6 mm diameter \times 1.2 mm length halfraums that are illuminated by the OMEGA laser at the University of Rochester. X-rays produced by the halfraum provide the drive for the sample. A streaked optical pyrometer detects breakout of the shock produced by the X-ray pulse. In this poster we describe the synthesis and characterization of the alloy material, fabrication of the samples, dimensional characterization of the samples, and assembly of the targets. The samples were produced from Be0.9%Cu alloy that was synthesized by hot isostatic pressing of Be powder and copper flake. Samples were 850 μ m diameter disks with varying thickness in the case of wedge and step samples, and uniform thickness in the case of flat samples. Sample thickness varied in the range 10-90 μ m. Samples were prepared by precision lathe machining and electric discharge machining. The samples were characterized by a Veeco white light interferometer and an optical thickness measurement device that simultaneously measured the upper and lower surface contours of samples using two confocal laser probes. Several campaigns with these samples were conducted over the past two years, and shock propagation and radiation burnthrough data on Be0.9%Cu material have been obtained.

Preferred Presentation Format – **Poster**

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Design of Z-Pinch IFE Target Assembly

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Abstract

Luxel has recently completed a Phase I Small Business Innovative Research (SBIR) project to develop methods to repetitively replace the target assembly in a z-pinch Inertial Fusion Energy (IFE) power plant. For Phase I, the design of the target assembly was taken from the Z-Pinch Power Plant (ZP-3) study led by the Sandia National Laboratories.

Luxel, in conjunction with General Atomics and Schafer Corp, completed the following tasks as part of the Phase I project:

- Fabrication of low-density foam cylinders (TPX and carbonized RF) including cylinders with spherical capsules imbedded in them.
- Development of methods to fabricate a leak tight membrane on the exterior surface of the foam cylinder.
- Assembly of prototype target assemblies.
- Leak testing of prototype target assemblies.
- Conceptual manufacturing study on mass-production of z-pinch IFE target assemblies.

The results of the Phase I project will be presented in this poster. In addition, the results have been summarized in the SBIR Phase II proposal which has been submitted to DOE. For Phase II, the Luxel/GA/Schafer team proposes to perform the following tasks:

- Update the z-pinch IFE target design based upon the latest Z-Machine shot results.
- Identify key issues in z-pinch IFE target fabrication and perform tests to resolve them.
- Perform tests to obtain the thermal and mechanical properties of low-density foam at cryogenic temperature.
- Update the thermal analysis of the ZP-3 target insertion process.
- Optimize production methods for low-density foam and polyimide membranes.
- Continue manufacturing study of mass-production of ZP-3 target assemblies.

Prefer poster presentation

Fabrication of Targets for Radiation Flow Experiments on the Sandia Z-Pinch Facility

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The “Z” Pinch pulsed power accelerator at Sandia National Laboratories is the world’s most powerful laboratory x-ray source. The drive pulse lasts less than ten billionths of a second. At Los Alamos, targets for radiation flow experiments in support of the Nuclear Weapons Program are being fabricated and fielded at Z. The two target types that are being fabricated are vacuum hohlraums and dynamic hohlraums. The vacuum hohlraum target contains anywhere from 4 to 13 different experimental packages that are placed around the circumference of a cylindrical hohlraum, which is about 1 inch in diameter. The Z pinch wire array that produces x-rays is placed along the axis of the cylindrical hohlraum. X-rays produced in the shot drive these 4-13 experimental packages. The experimental packages consist of tubes where radiation flow is studied, or free-standing silicon aerogel components to investigate radiation flow through free standing silicon aerogel. Recent new developments in vacuum hohlraum targets include placement of multiple low density (25 mg/cc) silicon aerogel components on the vacuum hohlraum. The development and assembly of these silicon aerogel components will be discussed. Another new development has been the ability to increase the number of experimental packages contained on the hohlraum. Vacuum hohlraums with as many as 13 experimental packages have been fabricated. Dynamic hohlraums consist of a single radiation flow package that is located above or below the Z pinch wire array. In recent experiments with dynamic hohlraum targets, the first Los Alamos images were obtained from the new backlighting capability at Z provided by the Z-Beamlet laser. These targets consisted of tubes that walls consisting of multiple layers of gold and aluminum. Diagnostic components that collect critical data from the shots are often an integral part of the target. Diagnostics such as fiber optic detection of shock breakout and VISAR detection of shock propagation are often a critical component of the target package. Some of the diagnostic components that are an integral part of the target package will be discussed.

Preferred Presentation Format – **Poster**

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Characterization of Fast Ignition Targets*

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Fast ignition is a novel scheme for achieving laser fusion. For recent campaigns, General Atomics has been fabricating and assembling cone mounted shells for use as fast ignition targets. The gold cone is inserted into a shell in order to provide a relatively clear path for the delayed high energy beam to reach the plasma core and ignite it. Consequently, the alignment of the tip of the cone with the center of the shell is critical. The axis of the cone is assigned to be the z axis (vertical). The crucial measurements are the height from the cone tip to the center of the shell along the z axis and the offset of the center of the cone tip from the center of the shell in an x/y plane (horizontal). This presentation describes the difficulties posed by the presence of the cone in the shell which blocks and/or scatters the light sources normally used for making many of the characterization measurements. The methods actually used to make the height and offset measurements are also presented as well as a brief discussion of the normal shell diameter, wall thickness, out-of-round, and non-concentricity measurements.

*This work was supported by the U.S. Department of Energy under Contract DE-AC03-01SF22266.

Surface Characteristics of Sputtered and E-Beamed Al Films on Extremely Smooth Surfaces*

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ICF program has continuing interests in very smooth coatings at different thicknesses. We obtained some extremely smooth (less than a few angstroms RMS) SiC substrates and used this opportunity to study the surface characteristics of Al films deposited by sputtering and e-beam depositions of various thicknesses.

Each substrate was characterized by WYKO before and after the coating. We will compare the surface characteristics of films of the same thickness that were deposited by different methods, and discuss the onset of surface roughness with increase of film thickness.

*This work was supported by the U.S. Department of Energy under Contract DE-AC03-01SF22266.

Comparisons of the Hardnesses, Compositions, and Microstructures of a Rolled High-Purity Gold*

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Electroplated gold coatings are employed in many ICF target components. There have been qualitative indications that this form of gold is relatively hard, but no quantitative measurements have been made. This study reports comparative measurements of the hardnesses of electroplated gold, rolled high-purity gold and OFHC copper. The electroplated gold is shown to be harder than the copper and of very high purity. The higher hardness of the electroplated gold is due to a very fine grain size

*This work was supported by the U.S. Department of Energy under Contract DE-AC03-01SF22266.

The Oxidation Characteristics of Sputtered Mg Films*

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We used an in situ measurement technique to characterize the oxidation of a sputtered Mg film which was continually contained in the coating chamber.

A Schafer customer required magnesium thin film standards. Knowing that a freshly deposited Mg film will be oxidized once it is exposed to atmosphere, it is important to know quantitatively the fraction of the Mg film that was oxidized. We developed a technique to make use of the frequency shift of the in situ oscillating crystal thickness monitor to quantify the oxidation process of the Mg film. Immediately after the completion of the coating run, a measured amount of O₂ was introduced into the coating chamber. The flow and pressure was monitored and the frequency shift was measured and compared. We will discuss the correlation between the shift and the oxidation characteristic of the Mg film.

*This work was supported by the U.S. Department of Energy under Contract DE-AC03-01SF22266.

« Polyimide membranes for LIL hohlraums »

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Polyimide membranes are one of the main piece in indirect drive targets and particularly for the Ligne d'Integration Laser facility (LIL). They must be very thin ($< 1 \mu\text{m}$) and contain gaz such as methane or pentane under 1 bar with the lowest permeation as possible at room temperature.

Specific home-made has been developped to synthesize self-supported membranes in a large range of thickness with low roughness. The studies consist in both decreasing the thickness and mesuring physics constants (permeation rate, burst pressure and curvature radius) to synthesize reproducible membranes.

Many reasons (and particularly thin thickness, needs of a reproducible process device) induce developpements on membranes assembling on test supports and hohlraums with special design of tools.

Lastly, a specific device to mesure permeation rate for LIL hohlraums under vacuum has been developped to simulate the target chamber environment. Interesting results have been obtained.

Target alignment process on the LIL target chamber

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In this paper, we present the principles and the different operational phases of the target alignment process on the LIL target chamber.

A high resolution metrology is used in a first step to define alignment parameter of each target. Then, these data are transmitted to the LIL control room in order to realize an automatic alignment of the target.

The mechanical and optical characteristics of this up to date metrology facility are discussed. The process of definition of the target reference system will be examined.

ISO 9001 in the Research Environment*

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In order to meet the developing needs of the ICF, IFE, & MFE programs physicists, material scientists, chemists, engineers, and technicians must be dedicated to describing every detail when defining the conditions of their experiment, process, and/or assembly. The inherent nature of such detailing requires all participants to be thorough in how they communicate among themselves, their staff, their supply networks, and the ICF, IFE, & MFE community as well. That's to say a holistic, and systematic approach is essential to the long-term health of any organization, and the ultimate goal of an inexpensive, and environmentally sound fusion energy source.

ISO 9001 is such a systematic approach. This presentation is an overview of how ISO 9001 can be implemented at any level in an organization to provide a quality management system for its user group. We will discuss how ISO 9001 principles can be tailored to perform in both the research, and production research environments. We will discuss how the ISO principles compartmentalize daily routines into quantifiable processes. We will present statistical data trending that provides an organization with valuable information on its performance. We will discuss how web-based/network computer information systems can provide a common reference location for data exchange varying from employee training, to process tracking, to strategic planning, to scientific analysis records just to name a few. We will discuss how such systems can save effort by reducing redundant communication, and paper at any level. Finally we will discuss how this systematic approach helps to strengthen the working relationships between an organization's customer base, its supplier network, its staff, and other ISO registered organizations through empowerment.

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Techniques for Assembling Capsules with Fill Tubes in NIF Scale Hohlräume*

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We describe techniques that are being developed at LLNL for constructing NIF scale thermally shimmed hohlraum ignition targets for layering studies. A fill tube technique for placing hydrogen fuel into the capsule offers some important advantages over permeation filling. One hohlraum target that we've constructed uses a 2mm. diameter fuel capsule with a 30 μ m diameter attached fill tube. The capsule is held in the center of the hohlraum with two pieces of Formvar film which form a tent. The fill tube passes between the two pieces of Formvar and through the side of the hohlraum. The most difficult part of this assembly was capturing the capsule and attached fill tube in the tenting film. Several methods were explored, each with their own set of problems. Details of the hohlraum assembly will be shown and we will evaluate the merits and weaknesses of the different assembly techniques for 30 μ m size fill tubes as well as smaller (10 μ m) tubes.

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The Megajoule Laser Cryogenic Target Assembly : Functions and Developments.

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To reach ignition on a megajoule laser facility, the cryogenic hohlraum of an indirect drive target needs to meet very severe thermal, mechanical, and dimensional specifications, coming from implosion physics designs.

For the LMJ project, a specific target assembly, which supports the cryogenic hohlraum, is filled in Valduc, and then sent in a transport cryostat to the laser facility in CESTA. This assembly has to integrate a lot of stringent functions towards :

- the DT filling under more than 1000 atm. of DT ¹ of a CH_x μ -shell ^{2 3 4 5}
- the He/H₂ filling of the cryogenic hohlraum to ensure a good X rays symmetry around the μ -shell during its implosion (polyimide membranes, magnetic screw design, target assembly below,...),
- the thermal specification to ensure a concentric DT layer,
- the vibrations at the center of the LMJ chamber,
- the positioning precision of the μ -shell at the geometrical center of the hohlraum,
- The activation and debris in the LMJ chamber,...

This paper describes the current design of the LMJ target assembly and details some of its main issues in terms of thermal specifications, filling, materials and also fabrication. Several critical issues have been solved :

- Stuck polyimide membranes on gold, with almost no leak toward helium, and resisting to more than one bar of pressure at 20K.
- High conductivity very pure aluminum turret fabrication,
- Low thermal resistance connection between the gold hohlraum and the aluminum.
- YAG welding of ultra pure aluminum to minimize the thermal resistance along the target assembly,
- High precision positioning of the μ -shell at the center of the hohlraum,
- Aging of the CTA components under several hundreds bars of tritium
- Complex target base fabrication compatible of the filling station and the LMJ cryogenic target holder, with a below to compress the He/H₂ mixture,...

¹ Ph. BACLET, E. FLEURY, JP PERRIN, D. CHATAIN « The Filling Facility for the Megajoule Laser Cryogenic Targets », Target Fabrication Meeting 99, 08-11 Novembre 1999, Catalina, Californie.

² O. LEGAIE, M. THEOBALD, Ph. BACLET, J. DURAND « Comparative Study of a-CH films for Inertial Confinement Fusion Prepared with Various Hydrocarbon Precursors by RF-PECVD », Target Fabrication Meeting 99, 08-11 Novembre 1999, Catalina, Californie.

³ M. THEOBALD, J. DURAND, Ph. BACLET, O. LEGAIE, « Comparative study of a-C:H films for inertial confinement fusion prepared with various hydrocarbon precursors by rf-PECVD », Journal of Vacuum Science and Technology A, Second Series, Vol. 18, N°1, Jan./Fev. 2000.

⁴ M. THEOBALD, Ph. BACLET, O. LEGAIE, J. DURAND « Properties of a-CH Coatings Prepared by PECVD for Laser Fusion Targets », Fusion technology, Vol. 38, July 2000, p 62-68.

⁵ M. THEOBALD, B. DUMAY, P. BACLET, « Thick GDP Microshells for LIL and LMJ Targets », 14th Target Fabrication Meeting, 15-19 Juillet 2001, West-Point, New-York

ABSTRACT
submitted to the 15th Target Fabrication Specialist Conference
June 1-5, 2003

Target Fabrication: a View from the Users

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Targets are used for a variety of purposes, but ultimately we use them to validate codes that help us predict new phenomena or effects. Targets are used more and more in complicated geometries whose sophistication increased in time to match the advances made in modeling complex phenomena. The targets have changed over time from simple hohlraums and simple spherical geometries to 3-dimensional geometries that require precision in construction and alignment. Furthermore, material properties, such as surface morphologies and volume texture, have significant impact on the behaviour of the targets and must be measured. In the following we will discuss how experimental physicists view targets and the influence that target construction has on interpreting the results. We review several targets that are used in different laser-based experiments in support of Inertial Confinement Fusion and High Energy Density Physics.

Thursday Oral Session

Cryogenic Target Characterization at LLE—A Status Report

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The cryogenic target characterization at LLE is presently based on shadowgraphy with multiple views at different angles. Data acquisition and reduction have been largely automated, and resulting $Y_{\ell m}$ decompositions and/or averaged Fourier spectra are available for input to hydrodynamic simulations and for evaluation of suitability for cryogenic target experiments. The automatic interpretation routines have been carefully checked for artifacts that could be introduced by the code as well as for limitations due to imperfect shadowgrams (breaks in rings), effects due to outer- and inner-surface slope errors, illumination, and imaging optics. Simulation tools have been developed to aid the detailed interpretation of the experimental results. The presentation will discuss the status of the cryogenic target characterization at LLE including an evaluation of the suitability of this approach for direct-drive NIF ignition target characterization.

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Recent Advances in Image Processing, and Analysis of Solid DT Surface Characteristics for DT Layers Produced in Spherical, Cylindrical and Toroidal Cell Geometries*

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Image processing and subsequent analysis of the image data are essential elements in the study of solid DT surface characteristics. These studies are performed during experiments that were designed to provide answers to important questions concerning the design and operation of Inertial Fusion Energy (IFE) reactors. Until recently, the image processing and data analysis have been handled by a combination of C⁺⁺ image processing software that was written in-house, and a commercial data processing and graphing software package. This combination has served us well for a number of years, but evolving requirements for a faster paced experimental schedule with ever changing solid DT cell geometries requires that our processing and analysis software have greater flexibility, power, and user friendliness. For these reasons LabView-based image processing and data analysis was chosen to replace our current software. The conversion from C⁺⁺ to LabView-based image processing and analysis is discussed in terms of programming ease, increased flexibility and generality, improved operator interface, and accuracy when compared to previous C⁺⁺ based analysis code. The processing and analysis of several image types will be shown, for images of empty beta-layering cells as well as images of solid DT layers that were produced inside toroidal and spherical cell geometries. A demonstration is performed, showing the comparative analyses of image simulations with known surface roughness characteristics, as well as on images of actual solid DT layers.

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A Shadowgraphic Analysis Procedure for Cryogenic Layer Characterization

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Abstract

Analysis of shadowgraphic images is fundamental in cryogenic layer characterization at LLNL and LLE. An analysis procedure was developed based on the geometric properties of shadowgraphic images. Unique features of this procedure include a circular interpolation method for conversion to polar coordinates, web/stalk and surface defect removal algorithm, and correction in the ring due to apparent ice layer breaks. Extensive evaluation of simulated images was performed to verify the robustness of these features and to assess the significance of numerical and experimental noise. These features have been incorporated into a data reduction analysis tool and have been applied to a variety of real and simulated cryogenic targets. An overview of the key components of this analysis procedure, noise analysis results, and results on simulated images, surrogate targets, and cryogenic images will be presented.

A MODEL FOR THE CHARACTERIZATION OF THE DT LAYER OF ICF TARGETS BY BACKLIT SHADOWGRAPHY

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The requirement of the ICF targets characterization needs the use of measurement techniques without contact. The inner surface of a spherical capsule shall be covered by DT ice layer and a precise knowledge of its thickness and roughness before laser shot is imperative. The backlit shadowgraphy is a relevant technique for optical diagnostic of the DT layer provided that the wall of the capsule is transparent. Because the lack of equivalent material which could be used as a surrogate of DT ice layer, a numerical 3D modelization of the based on spherical Legendre's harmonics was performed. The facets of the ice can also be modeled. The shadowgraphs are simulated with a ray-tracing software. The simulated images show a circular brightband due to multiple reflexions in the layers confirmed by experimental data. A mathematical model was developed to link the radius of the brightband to the effective radius of the ice layer. The relationship between the roughness and deformation of the ice layer and the position of the brightband was analyzed. We stated that a perfectly spherical and smooth DT layer leads to a measured RMS roughness of $0.7\text{ }\mu\text{m}$ on the shadowgraphic image with a sampling of $2.5\text{ }\mu\text{m/pixel}$. Simulations of a layer with a 10 Legendre's mode of $1\text{ }\mu\text{m}$ RMS roughness was performed and $1.23\text{ }\mu\text{m}$ RMS value was found. The simulated and measured Fourier's power spectrum are compared. Several simulated low modes shadowgraphs corresponding to previsible thermal defects in the cavity for indirect drive target are shown. These simulations will provide a knowledge base for the future IR redistribution experiment in indirect drive ignition target at Valduc.

3-D RECONSTRUCTION OF SPHERICAL ICF TARGET INNER SURFACES USING OPTICAL BACKLIT SHADOGRAPHY.

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We have developed a method of 3-D inner surface shape reconstruction for spherical shells with a solid internal cryogenic fuel layer using a set of 2-D backlit shadowgraphs. Essential for this is our ray-trace model which allows us to carry out a detailed investigation of bright ring formation for shells and multi-layer transparent targets, localizing the rays forming the bright ring, and allowing us to produce a complete description of the ray path through the capsule. Based on this analysis algorithms for the determination of the 2-D inner ice surface shadowgraph shape and shell wall thickness have been developed. Using the results of the independent 2-D shadowgraph analyses we have developed the tools to allow us to reconstruct the 3-D inner surface using a set of images, and to visualize the shape and relative position of the inner surface. To validate the methods 60 images of a two-layer shell were generated and an accurate 3-D reconstruction of the object was achieved. We have also used these methods to reconstruct the interior surface of a simple plastic shell using experimentally acquired images. In this report we discuss the methods and algorithms used in developing our software package, present the results of our validation tests, and discuss our plans to apply these methods to the determination of the 3-D inner surface of a solid hydrogen ice layer in a plastic capsule.

Part of this work had been carried out under the support of the International Science and Technology Center (ISTC project #1557).

Solid DT Studies in Support of Inertial Fusion Energy*

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ABSTRACT

We discuss ongoing work at Los Alamos to study the feasibility of cryogenic targets for IFE applications. These include:

- an experiment to measure the response of a uniform layer of solid DT to a high heat flux,
- an experiment to measure the modulus and yield strength of solid DT, and
- measurements of the solid DT surface spectrum following beta-layering inside a layer of foam.

These topics address the general problem of cryogenic target survivability during injection into a fusion reaction chamber. For instance, the yield strength of solid DT may well prove to be too low to support the high g-loads currently being proposed for target acceleration.

Because the reaction chamber walls will be very hot, the thermal load on the target is high. Most of the energy absorption occurs in the thin plastic outer shell of the target, which then transfers heat to the inner solid DT fuel layer via conduction. When the heating time is sufficient to cause gross perturbations to the fuel layer, ignition may no longer be possible. Knowing the expected practical ‘lifetime’ of the target then puts an upper bound on the necessary injection speed that in turn affects the injector length and/or accelerative g-loading.

Intermediate foam layers complicate the problem of target lifetime. On the one hand, the foam plastic also absorbs heavily in the infrared. However, the presence of fine-grain-sized foam allows the inner, pure DT fuel layer to form with a smoother inner surface, possibly delaying the time when unacceptable roughening would occur. Our recent data on this effect will be presented.

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(oral presentation preferred)

Precision Manufacturing of Double Shell Laser Targets
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Abstract

Lawrence Livermore National Laboratory (LLNL) manufactures laser targets for experiments on the Omega laser at the University of Rochester and is preparing to build targets for the National Ignition Facility (NIF). These targets serve university collaborations, high energy density physics studies, and inertial confinement fusion (ICF) customers. Of particular interest to ICF studies are high-precision double-shell implosion targets for demonstrating thermonuclear ignition without the need for cryogenic preparation. Because the ignition tolerance to interface instabilities is rather low, the manufacturing requirements for smooth surface finishes and shell concentricity are particularly strict. As a prelude to fabricating and fielding ignition double-shell targets on the NIF, an effort is underway on the Omega laser facility to build and field scaled ignition-like double-shells. These Omega double-shell targets are composed of an inner 244 μm plastic capsule surrounded by low density foam and covered by an outer layer consisting of a polystyrene shell 52 μm thick with an outside diameter of 550 μm . Previous literature in the 1980's and the 1990's introduced the manufacture of double-shell targets using methods that by definition introduce uncertainties into the manufacturing process, such as coating mandrels and releasing free-standing components, or adding binder materials to allow machining of components and extracting this material and dealing with part shrinkage. This presentation will focus on a systematic, deterministic approach to controlling error sources in each component, and an error budget will be presented. The manufacturing plan developed for this effort created a deterministic process that, once proven, is repeatable over time. By taking this rigorous approach to controlling all error sources in each component and during the assembly, one can attempt to achieve this overall $\pm 5 \mu\text{m}$ dimensional requirements with sub-micron surface flaws. This development process allows one to systematically study the manufacturing process and identify errors at each step, so they can be quantified and improved upon in future builds.

The design process, materials, manufacturing, and characterization of these targets will be discussed. Details of the manufacturing steps will be outlined, and manufacturing and material issues with polystyrene will be discussed. The diamond turning, fixturing, and chucking techniques, along with an overview of the machining conditions will be presented. The manufacturing steps will highlight how each component is built with known datums and how these are maintained during the entire manufacturing process. The assembly and joining processes are critical to achieving a concentric target, and these steps will be discussed in detail. LLNL has manufactured double shell targets to $\pm 5 \mu\text{m}$ concentricity, providing physicists with a target that may yield improved performance. Strengths and weaknesses in this manufacturing process will be discussed.

Key Words: Meso-scale, double shell laser target, precision machining, diamond turning, National Ignition Facility.

Cutting Tool Selection and Tool Life When Micromilling Rolled High Purity Gold*

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During micromilling of rolled high-purity gold the carbide mills dull very quickly and this leads to rough-cut surfaces and large burrs left behind on the surface of the part. Carbide mills are available in a variety of application specific coatings. These coatings are designed to enhance performance as well as the life of the tool. The surface finish and tool life on rolled high-purity gold was investigated as a function of carbide mill coating composition.

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Techniques for Fabricating the Window Saddles of NIF Cryogenic Hohlraums*

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The design of components for NIF is getting more complicated which requires that these components be fabricated using a combination of diamond turning and micromilling operations. One such component is a window saddle for NIF cryogenic hohlraums. The techniques that were employed to fabricate this window will be described, starting with mandrel design and finishing with micromachining to final dimensions.

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Production and Metrology of Cylindrical Inertial Confinement Fusion Targets with Sinusoidal Perturbations

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Shock waves generated during inertial confinement fusion (ICF) implosions propagate toward the center of the capsule, encountering interfaces between materials with different densities, such as between the ablator and the DT fuel. These interactions are hydrodynamically unstable and the resulting instability causes mixing of the materials at the interface, which has detrimental effects on fusion burn. In this experiment the growth of a single-mode perturbation machined into a radiographically opaque marker layer is measured during a cylindrically symmetric implosion. These measurements are used to validate simulations and theories of the complex hydrodynamics. Since any perturbation on the marker layer surface will lead to instability growth, precise knowledge of the initial conditions is critical. The targets have up to a 3.0 micron amplitude, $m=28$ ($\lambda=98$ micron) perturbation machined into a 438-micron-radius aluminum band with a nominal thickness of 8 microns. The perturbations were machined at the North Carolina State University Precision Engineering Center using a fast-tool servo and were metrologized using an LVDT. In this presentation, the importance of metrology is discussed, and the design, manufacture, and metrology of the single-mode targets are presented along with experimental results.

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